PHORATE (OPP # 34137)

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A

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GOOD LABORATORY PRACTICES COMPLIANCE STATEMENT

This submission is not a study.

There is no data collection directly associated with this report. Therefore it was not conducted according to GLP regulations (40 CFR Part 160).

American Cyanamid Company
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Executive Summary

This document presents an ecological risk assessment of the agricultural use of THIMET® Soil and Systemic Insecticide. Ecological risk assessment is a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more environmental stressors. A wide variety of sources including laboratory and field studies with THIMET[1]® and field incident reports were evaluated to assess the potential risks to fish and wildlife from the continued agricultural use of the pesticide.

THIMET® was introduced in 1956 for control of thrips, aphids, and mites on cotton. During the late 1950s and 1960s, it was registered as an insecticide on potatoes, corn, and other crops. Currently, 95% of the volume of THIMET® sold is used on six crops: field corn (44%), potatoes (21%), cotton (19%), peanuts (5%), sweet corn (3.9%), and sugarcane (3.4%). The remaining volume is applied to dry beans, sugar beets, grain sorghum, wheat, and soybeans. The original formulated product THIMET® 10G contained 10% active ingredient on clay granules. Since that time, THIMET® has been produced as a 15 G formulation and currently is registered as 20G formulation(EPA Reg. No. 241-257). In 1991, THIMET® was introduced in the LOCK'n LOAD® closed handling system developed to reduce pesticide exposure to growers. This system uses returnable and refillable containers, eliminating the need for burying or burning empty insecticide bags.

The active ingredient of THIMET® is phorate, an organophosphate insecticide. Like other organophosphate pesticides, phorate acts by inhibiting the action of the enzyme cholinesterase that is essential to nervous system function in invertebrates and vertebrates. Phorate is metabolized relatively rapidly in animal tissues, so it does not bioaccumulate. However, short-term laboratory studies have shown that it is highly toxic to fish and wildlife.

The U.S. Environmental Protection Agency (EPA) uses information from laboratory toxicity studies together with information on the availability of the pesticide in the environment to calculate indices of the risk of adverse effects to fish and wildlife. For birds and mammals, the LD_{50}/ft^2 index is used. This risk index calculates the amount of active ingredient, expressed as multiples of the LD_{50} (i.e., single dose lethal to 50% of test animals), exposed per unit area of the crop row. For aquatic organisms, the risk index is the predicted concentration of pesticide in water divided by the LC_{50} (i.e., the aqueous concentration of pesticide lethal to 50% of the laboratory population of fish or invertebrates). If the value of the index exceeds the established regulatory "level of concern", a determination will be made that the use of the pesticide poses potentially

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unacceptable risks. The risk index approach is properly used as an initial screening tool and pesticides that are identified as posing potentially unacceptable risks are subject to more detailed evaluation, including evaluation of field studies and incident data, and the assessment of risk mitigation options.

The EPA has determined that the currently registered uses of THIMET® exceed the levels of concern for aquatic and terrestrial wildlife, based on laboratory data. Based on current application methods and rates, the calculated LD_{50}/ft^2 index values in this assessment ranged from 0.7 for bobwhite on wheat to 785 for red-winged blackbirds on cotton. The level of concern established by EPA is 0.5 for acute exposure. It is assumed that the higher the index value the higher the risk to birds, but the relationship between the index and actual risk in the field is unknown.

Field and simulated field studies have been conducted to clarify the potential risks. In a field study, few carcasses were found after applications at planting and at cultivation; only one mammal, a raccoon, contained detectable residues of phorate. Surveys of birds at field sites before and after applications did not detect changes in the numbers of birds, bird species, or number of singing males related to THIMET®. Simulated field studies on corn fields or small ponds showed the potential for THIMET® to kill birds under the conditions of the studies. However, the studies on corn may represent worst case scenarios using an application rate twice the current labeled rate and placing supplemental feed in turn row areas, thereby increasing potential for accidental ingestion. Pond studies simulated a direct application of granules to the pond and shoreline, but current ground application methods are unlikely to present that type of exposure scenario.

Besides field studies, EPA uses wildlife incident reports to evaluate effects under actual use. THIMET® has been used on millions of acres of cropland in over 40 years of registered use. Of 17 terrestrial wildlife incident reports listed in EPA's Ecological Incident Information System related to THIMET®, seven represent cases of misuse or misapplication, one may have been a spill, and one was determined not to be related to phorate. Also, two (and possibly three) seem to be duplicate reports of the same incident in Hughes County, South Dakota. Of the six phorate-related incidents not identified as cases of misuse (assuming the three listed for Hughes County, South Dakota, are the same incident), three occurred in wheat, one in sugar beets, and two did not have a specified crop. The largest bird kill reported (i.e., over 2000 birds in a wheat field in California in 1982) was an aerial application, which is no longer a registered application method for THIMET®. Consequently, the weight of evidence suggests that while phorate is highly toxic to wildlife, agricultural uses of THIMET® do not suggest a pattern of repeated mortality and/or reproductive effects sufficient to impact populations of terrestrial wildlife. The greatest risk to wildlife from THIMET® may be under conditions where treated fields are temporarily flooded by rainfall or irrigation or where phorate enters shallow waterbodies (e.g., ponds, drainage ditches) during periods of field runoff.

Calculated theoretical risk indices for fish and aquatic organisms exceed the regulatory level of concern for acute and chronic effects. However, in an experimental pond study, no apparent treatment-related effects were observed on populations of phytoplankton, zooplankton, macroinvertebrates, and fish following applications of THIMET® 20G to fields adjacent to the test ponds. Field incident data demonstrate that risks to aquatic ecosystems also are highly variable because exposure is dependent on heavy rainfall events that result in pesticide movement from treated fields to nearby small water bodies that are vulnerable to runoff. These aquatic systems, many of which are constructed to control runoff, are disturbed and unstable ecosystems that are subject to a number of human-related and natural stresses and are not typically considered important habitat for aquatic organisms. Consequently, the weight of evidence identifies specific conditions where phorate may adversely affect aquatic organisms in very localized settings (e.g., farm ponds adjacent to corn fields after heavy rains), but does not indicate a repeated pattern of mortality sufficient to impact regional populations of aquatic organisms or a threat to populations in streams, rivers and lakes.

In summary, information from laboratory toxicity studies, field and simulated field studies, fish and wildlife incident reports, and measured and estimated exposure concentrations was reviewed to assess the ecological risks of the use of THIMET® Soil and Systemic Insecticide to fish and wildlife. While laboratory and simulated field studies of THIMET® demonstrate that its active ingredient, phorate, is highly toxic to fish and wildlife, a review of field studies and the conditions leading to incident reports indicates that wildlife mortalities are usually associated with treated fields that are temporarily flooded by rainfall or irrigation or where phorate enters shallow waterbodies (e.g., ponds, drainage ditches) during periods of field runoff. Many of the reports of wildlife mortalities are cases of misuse or application methods that are not supported on the current label. Consequently, the weight of the evidence indicates that while there is a risk of acute mortality under certain exposure conditions, overall there is not evidence of widespread and repeated mortality to fish and wildlife.

This assessment, as well as the ecological risk assessment conducted by USEPA, uses deterministic quotient indices to characterize risks and therefore represents a first tier screening assessment. This assessment also integrates laboratory data with data from field studies and incident reports to develop a narrative synthesis of the overall risks to fish and wildlife. As suggested by the Aquatic Risk Assessment and Mitigation Dialogue Group (1994) and again by the USEPA Science Advisory Panel in May, 1996, probabilistic risk assessment may be a more appropriate approach to characterization of ecological risks for making regulatory decisions.

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1. Introduction

The ecological risk assessment of THIMET®[3] Soil and Systemic Insecticide is based on the *Framework for Ecological Risk Assessment* (USEPA 1992a). The framework defines ecological risk assessment as:

> a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. A risk does not exist unless 1) the stressor has the inherent ability to cause one or more adverse effects and 2) it co-occurs with or contacts an ecological component (i.e., organisms, populations, communities, or ecosystems) long enough and at sufficient intensity to elicit the identified adverse effect (USEPA 1992a).

The ecological risk assessment process has three primary phases: problem formulation, analysis, and risk characterization (Figure 1). The Problem Formulation phase integrates the regulatory and policy issues with scientific data to develop the scope and objectives for the assessment. The Analysis phase integrates available data into a characterization of the exposure patterns of the stressor and potential effects in the environment. The Risk Characterization phase evaluates the likelihood of adverse effects resulting from exposure to the stressor and the ecological significance of those effects.

There are several related components to the regulatory process that fall outside the ecological risk assessment process, but are integral to making regulatory decisions. Environmental policy and risk managers (i.e., decision makers) have a critical role in shaping the direction and scope of the process during the Problem Formulation phase. Data acquisition and monitoring, while outside of the ecological risk assessment process, provide input during all phases of the risk assessment. Finally, the output of the ecological risk assessment process moves on to the risk manager for consideration in the decision making process. In some cases, the risk manager may balance the ecological risks against an assessment of the benefits (economic and ecological) before making a decision. The assessment of benefits occurs outside the ecological risk assessment process.

Ecological risk assessments are subject to revision as additional information becomes available. This assessment of THIMET® Soil and Systemic Insecticide reflects data from a wide variety of sources such as laboratory and field studies with THIMET® and related studies on granular pesticides and the ecology of agricultural ecosystems.

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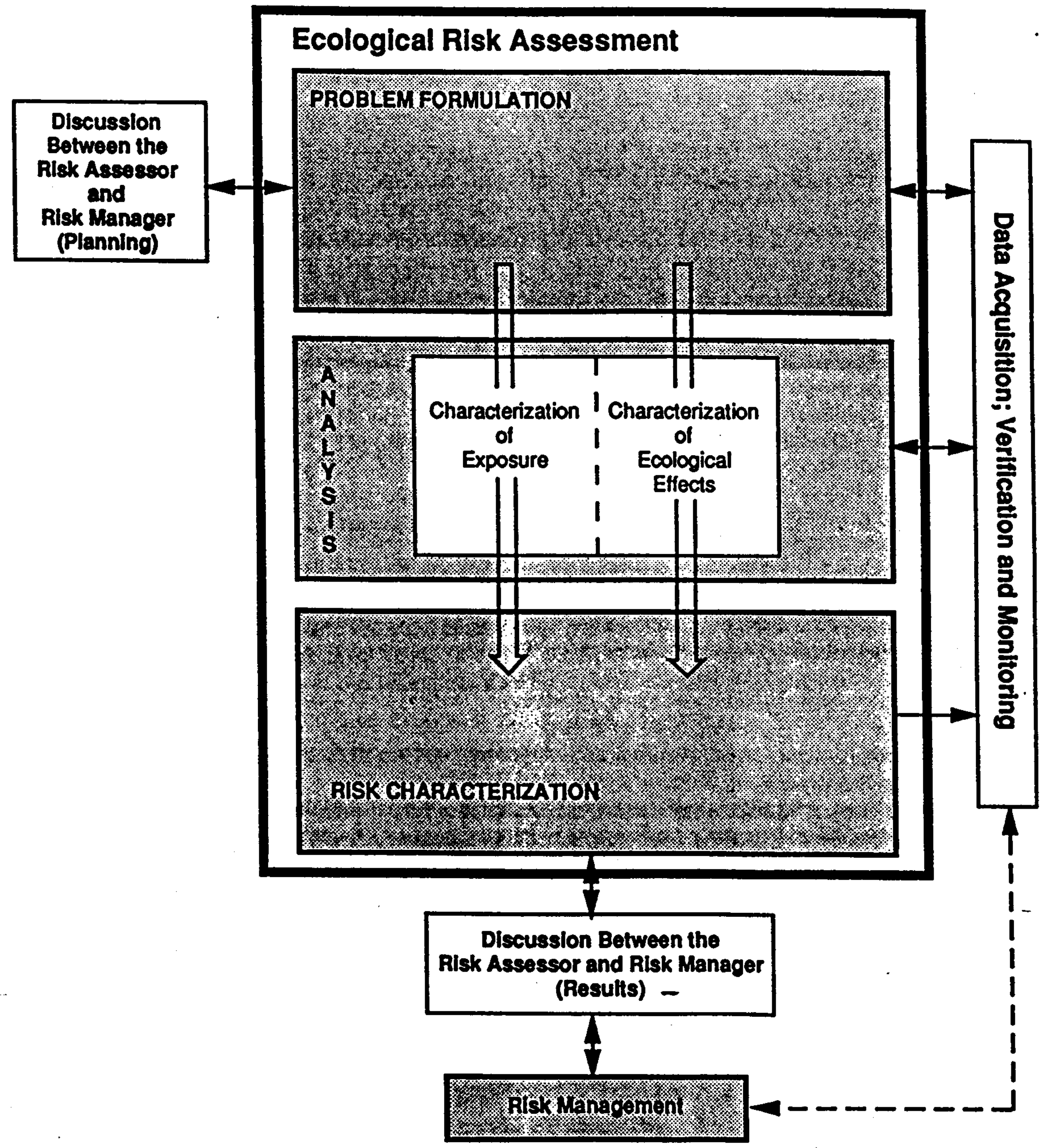

Figure 1. Framework for ecological risk assessment (from EPA 1992a).

2. Problem Formulation

The Problem Formulation section of the ecological risk assessment identifies the major factors to be evaluated and establishes the goals, breadth, and focus of the assessment. This section defines the characteristics of THIMET®, the ecosystems potentially at risk from the use of THIMET®, and the potential ecological effects, culminating in a conceptual model that guides the assessment.

2.1. Background

THIMET® is a granular insecticide containing the active ingredient phorate. It was introduced in 1956 for control of thrips, aphids, and mites on cotton. During the late 1950s and 1960s, it was registered as an insecticide on potatoes, corn, and other crops. The original formulated product THIMET® 10G contained 10% active ingredient on clay granules. Since that time, THIMET® has been produced as a 15 G formulation and currently is registered as 20G formulation(EPA Reg. No. 241-257). In 1991, THIMET® was introduced in the LOCK'n LOAD® closed handling system developed to reduce pesticide exposure to growers. The system uses returnable and refillable containers, eliminating the need for burying or burning empty insecticide bags.

Broadcast or "over the top" uses via both ground and aerial equipment have been deleted from the label for major crops such as corn, grain sorghum, and wheat. Additionally, the aerial application has been discontinued on all crops. These changes to THIMET® labels have reduced environmental exposure from phorate by eliminating the application methods with the greatest potential for wildlife exposure.

The annual volume of THIMET® sold typically ranges between 15 and 20 million pounds of formulated product (i.e., 3 to 4 million pounds of active ingredient) based on acreage and market share variation. It is sold in both bags and the LOCK'n LOAD® closed handling system. In 1997, over 65% of the THIMET® grower sales were in LOCK'n LOAD® and only the 20G formulation was manufactured for sale in the U. S.

Ninety-five percent of the volume of THIMET® sold is used on six crops: field corn (44%), potatoes (21%), cotton (19%), peanuts (5%), sweet corn (3.9%), and sugarcane (3.4%). The remaining volume is applied to edible beans (dry and succulent), sugar beets, grain sorghum, wheat, and soybeans.

Table 1. Maximum volume of THIMET® sold and percent active ingredient applied by major crop type for 1994-1996.[a]						
Crop	**Cotton**	**Field corn**	**Potatoes**	**Sugarcane**	**Peanuts**	**Sweet corn**
1994-96 Volume (thousand pounds)	785	1860	878	143	211	166
Percent of total	18.6%	44.1%	20.8%	3.4%	5.0%	3.9%
[a] Doanes Market Research Data Base						

2.2. Pesticide Characteristics

Phorate is an organophosphate insecticide with a molecular formula of $C_7H_{17}O_2PS_3$ and a molecular weight of 260.37 (Table 2). Its mode of action is to inhibit the activity of the enzyme cholinesterase, which breaks down the neurotransmitter acetylcholine in nerve synapses. When an organophosphate pesticide molecule chemically binds to a cholinesterase molecule, the activity of the enzyme is said to be inhibited. Inhibition of cholinesterase leads to a build-up of acetylcholine at the synapse, which overstimulates the nervous system and eventually can lead to death.

Table 2. Description and chemical characteristics of Phorate.	
Chemical name	O,O-diethyl S-[(ethylthio)methyl] phosphorodithioate (IUPAC)
Chemical Abstracts Service (CAS) Number	298-02-2
EPA Shaughnessy Code	057201
Pesticide Type	Soil and systemic insecticide
Color	Colorless to very light yellow
Physical State	Liquid
Odor	Mercaptan odor
Boiling Point	118-120 °C

Phorate currently is marketed in one granular formulation. The THIMET® 20G granules are brown to gray in color. Both have a mercaptan-like odor.

Two studies have been conducted where the weight of THIMET® 15G granules was measured. Balcomb *et al.* (1984) reported a mean granule weight of 0.092 mg with a 95% confidence interval of 0.079-0.104. Hill and Camardese (1984) reported a median granule weight of 0.085 mg with a range of 0.067 to 0.143 mg. Consequently, a granule weight of approximately 0.09 mg contains 0.0135 mg of the active ingredient phorate.

Best (1992) reported that the average size of THIMET® 20G granules is 0.6 mm based on measurements of 500 granules, with granules ranging from 0.2 to 1.2 mm. If the weight of a THIMET® 20G granule is similar to that of the 15G product, a 0.09 mg granule would contain 0.018 mg of phorate.

2.3. Ecosystems Potentially at Risk of Exposure to THIMET®

THIMET® is registered for use primarily on field corn, cotton, potatoes, sugarcane, and peanuts. It also is used on minor crops such as dry edible and snap beans, sugar beets, sorghum, wheat, and soybeans. Also, THIMET® is registered for use on specific pest species and pest complexes that vary geographically. Consequently, THIMET® may be used where these labeled crop/pest overlaps exist and where it has demonstrated efficacy. In general, THIMET® is used in the corn belt states, the southeastern coastal plain, the lower Mississippi valley, and several crop growing regions of Texas and the western states. This assessment does not attempt to evaluate the differences in risk among geographic regions.

The quality of wildlife habitat in agricultural regions varies greatly, from broad expanses where intensive row crop rotations and monocultures provide little in the way of wildlife habitat to areas of smaller field sizes and greater diversity in land use (i.e., mixture of row crops, pasture, hay, woodlots and riparian habitats). Wildlife use of crop fields treated with THIMET® will be a function of the species present at a specific site, the availability of habitat suitable to those species near the crop fields, and climatic factors that influence wildlife distributions (e.g., rainfall patterns with extremes of drought or floods). Many crop fields at planting provide little or no cover to wildlife, but may be a valuable source of food.

2.4. Potential Ecological Effects

Phorate, the active ingredient of THIMET®, is an organophosphate pesticide whose mode of action is to inhibit the action of cholinesterase in vertebrates and invertebrates. Exposure to cholinesterase-inhibiting pesticides can result in several types of effects, including acute mortality, and a variety of sublethal, behavioral and physiological effects with the potential ultimately to affect survival and reproduction of individuals. Organophosphate pesticides can be acutely toxic to wildlife as evidenced by the number of reported field kills of wildlife (see review by Grue *et al.* 1983). Death is believed to be from asphyxiation, due to the over stimulation of nerves of the central nervous system that results in respiratory failure. Wildlife also can recover from sublethal exposures by the dephosphorylation of the inhibited cholinesterase and synthesis of new uninhibited enzyme (Grue *et al.* 1991). Recovery of brain cholinesterase activity is dependent on the chemical and the degree of enzyme inhibition.

Organophosphate pesticides have been observed to produce changes in the behavior of birds that affect foraging and reproduction (see review by Bennett 1994). In the laboratory, significant reductions in food consumption are observed in feeding studies. Many of the effects observed on avian reproduction in the laboratory are related to the reduction in food consumption, which reduces the intake of protein and nutrients for normal egg production. Sublethal exposures to organophosphate pesticides have also resulted in changes in reproductive behaviors in birds at several periods, including pairing and nest building, egg laying, incubation, and rearing of young. Nest and brood abandonment have been documented after field applications of organophosphate pesticides. However, sublethal and chronic effects of organophosphate pesticides to wild birds are still poorly understood.

In anticipating potential impacts, it should be recognized that organophosphate compounds generally have low environmental persistence and have little potential to accumulate in food chains. Moreover, the types and magnitude of effects seen with organochlorine chemicals have not occurred with organophosphate pesticides (Hall 1987).

This ecological risk assessment will evaluate available information on all types of effects, but organophosphate pesticides in general have limited environmental persistence and are metabolized rapidly in animal systems, so the greatest risk is expected to be from acute poisoning rather than chronic effects. Like other organophosphate pesticides, phorate is not expected to bioaccumulate in animal tissues. The degree to which the effects described above occur in the field from the use of a pesticide is a function of 1) the toxicity of the pesticide, 2) where it is applied in relation to wildlife habitat, 3) the amount applied over a given period of time, 4) the persistence of the active ingredient and its toxic metabolites, and 5) its potential to bioaccumulate (Smith 1993). The types of effects observed will also be a function of the most common pathways of exposure, which are described in Section 2.6, Conceptual Model.

2.5. Endpoint Selection

An endpoint is "a characteristic of an ecological component (e.g., change in rate of mortality of fish) that may be affected by exposure to a stressor" (Suter 1990). Two types of endpoints are used in ecological risk assessments: assessment endpoints and measurement endpoints.

2.5.1. Assessment endpoints

According to the *Framework for Ecological Risk Assessment* (USEPA 1992a) "Assessment endpoints are the ultimate focus in risk characterization and link the measurement endpoints to the risk management process." Recent documents and decisions by the EPA have clarified that the Agency is concerned about effects to individuals and populations. It is stated in the *Comparative Analysis of Acute Avian Risk from Granular Pesticides* (USEPA 1992b) that:

> Both pesticide-induced bird mortality and population effects are impacts of concern to EPA. However, a recent Agency decision has established that there is no need to demonstrate population effects before taking regulatory action. In the Diazinon Remand Decision, Administrator William K. Reilly states, "the Agency's concern for wildlife is not limited to long-term adverse effects on populations. Absent some countervailing benefit of continued use, as a matter of policy an unnecessary risk of regularly repeated bird kills will not be tolerated" (USEPA, 1990).

In a memorandum dated 29 October, 1992, Linda J. Fisher, Assistant Administrator for the Office of Pesticides and Toxic Substances, stated that the re-registration process for pesticides would focus primarily on the "level of concern" derived from quotients calculated by comparing the estimated environmental concentration with a measure of laboratory toxicity from acute or chronic tests. Specifically, for avian wildlife, Fisher stated that the standard for assessing a pesticide is the occurrence of "widespread and repeated mortality in the face of minor economic benefits to society." The memorandum does not define what constitutes "widespread" or "repeated," but states that "the 'widespread and repeated' standard can be met on a local or regional as well as a national basis."

The assessment endpoint for this ecological risk assessment of THIMET® is survival and reproduction of fish and wildlife, with special emphasis on determining if avian mortalities are widespread and repeated under field use conditions.

2.5.2. Measurement endpoints

Measurement endpoints represent the specific measurements of responses to pesticide exposures that can be made in laboratory and field studies that are related to the established assessment endpoints. Standardized avian and aquatic laboratory studies have established measurement endpoints such as median lethal dose (LD_{50}), median lethal concentration (LC_{50}), no-observable-adverse-effect level (NOAEL), lowest-observable-adverse-effect level (LOAEL), and maximum acceptable toxicant concentration (MATC).

Field studies reviewed in this assessment evaluated wildlife survival by measuring the number of dead animals collected during carcass searches. Simulated field studies measured the percentage of marked animals surviving specific time intervals. Residue analysis of gastrointestinal tract contents and measurement of brain and plasma cholinesterase activity were used as diagnostic tools for determining the cause of death in wildlife incident reports and the proportion of the marked population exposed to the pesticide in simulated field studies.

2.6. Conceptual Model

2.6.1. Terrestrial Effects

The purpose of the conceptual model is to define the sources of the pesticide, potential routes of exposure, and the most probable biotic receptors. Several potential routes of exposure must be considered in order to identify the most significant exposure pathways to fish and wildlife. Best and Fischer (1992) discuss the potential routes of exposure of granular pesticides to birds, including inhalation, dermal, accidental ingestion, ingestion of contaminated prey, ingestion of plant material with pesticide residues, ingestion of granules mistaken for food, and ingestion of granules as a source of grit.

Inhalation is not likely to be a significant route of exposure to wildlife because granular pesticides are specifically formulated to reduce dusts during handling and application. THIMET® with the LOCK'n LOAD® system is designed to eliminate human exposure through inhalation and dermal contact. Consequently, inhalation exposure to wildlife is minimized.

Wildlife may be exposed dermally from granules in or on the soil by 1) direct contact to feet from walking, 2) probing in the soil for food or grit, or 3) dust bathing (Best and Fischer 1992). The relative importance of these routes of dermal exposure is unknown and is a function of the behavioral characteristics of each wildlife species and the environmental conditions at the time of exposure. Possibly the greatest risk from dermal exposure exists if birds dust bathe in an area where a spill of granular product has occurred. THIMET® with the LOCK'n LOAD® system is designed to eliminate spills by using a closed handling system with refillable containers that only open when attached to the planter equipment.

Ingestion is probably the most important route of exposure, but there are many pathways by which wildlife species ingest granules or the residues from granules. These pathways range from accidental, where granules are ingested as a random function, to intentional, where wildlife purposefully select for granules as food, as grit, or because of their novelty. The *Comparative Analysis of Acute Avian Risk from Granular Pesticides* (USEPA 1992b) assumed in its assessment that granules were consumed by birds at random rather than intentionally. In that assessment, avian risk was assumed to be directly related to the amount of exposed active ingredient after application. However, it was recognized in that comparative analysis that risk estimates may change if additional information indicates that granular ingestion by birds is intentional, either as grit or mistaken for food.

Accidental or random ingestion may be most likely to occur in species that probe for food in or on the soil for seeds, sprouting seedlings or invertebrates. Granules may be included with other extraneous material during feeding or may adhere to food items such as earthworms (Best and Fischer 1992). During rainfall events, waterfowl may inadvertently ingest granules while sieving through wet soils in puddles and flooded fields.

Intentional ingestion of granules can occur if birds mistake the granules for food items or use them as a source of grit. Mistaking granules for food is most likely with granivorous birds. In a comparison of the size and shape of seeds commonly found in rowcrop fields of the Midwest with several of the granular insecticides used in corn, Best and Fischer (1992), citing unpublished work by L. Best, stated that most available seeds are larger and differently shaped from most granular products.

Intentional ingestion of granules as grit is influenced by several factors, including 1) availability, 2) bird behavior, 3) grit/granule characteristics preferred by birds, and 4) grit retention in the gizzard (Best and Fischer 1992). Best and Gionfriddo (1994) found that house sparrows strongly preferred silica granules over other materials commonly used in granular formulations. Best and Gionfriddo (1991a) found that silica particles persisted far longer in the gizzard of house sparrows than other materials used for pesticide granules. The authors concluded that particles that break down rapidly, such as clay granules, probably do not function as grit and do not provide the tactile stimulus in the gizzard typical of grit. The clay granules used for THIMET® 20G may not be viewed by birds as an adequate source of grit. The inert material used for THIMET® is rather soft and does not look or feel like silica.

The active ingredient also may be ingested through the food chain by consuming prey items, such as insects, or plants containing residues from granular products. Most insecticides are more toxic to insects than to birds, so residues in invertebrate foods often do not reach levels that are toxic to birds. Best and Fischer (1992) provide an example from Johnson *et al.* (1989) where insects from potato fields treated with granular disulfoton contained a mean concentration of 0.43 ppm of the parent and/or toxic metabolite (range 0.09 to 5.2 ppm). Consequently, a bird would have to consume 290 insects weighing 100 mg to obtain the same amount of active ingredient as a single granule of Di-syston® 15G.

Carnivorous wildlife may also be exposed from prey containing residues of phorate. Like most organophosphate pesticides, phorate is not expected to accumulate in tissues of vertebrate prey, due to its rapid metabolism by organisms. However, carnivores like hawks and owls may be exposed by consuming the gastrointestinal tracts of small mammals and birds containing granules or residues of phorate. The threat to carnivores will be a function of the frequency and magnitude of residues in the ingesta of prey species.

The amount of active ingredient translocated into plant leaves and shoots from systemic insecticides also is not expected to constitute a significant avian risk due to the volume of plant biomass that birds would need to ingest to produce toxicity (Best and Fischer 1992). Also, there are relatively few birds for which plant leaves and shoots constitute a large proportion of the diet (e.g., some waterfowl).

2.6.2. Aquatic Effects

The conceptual model for aquatic organisms is simpler than for terrestrial species because the principal route of exposure is via contact with water borne residues, rather than the several different types of oral ingestion described for terrestrial organisms. Although the likelihood of direct applications to water bodies is extremely small because the only labeled uses for all crops are applied by ground equipment, there is the potential for phorate and its degradates (i.e., phorate sulfoxide and phorate sulfone) to be transported to water bodies via runoff from rain events. Runoff events, especially from very heavy storms, may carry dissolved or adsorbed phorate and its degradates into field puddles and permanent waterbodies in concentrations sufficient to be toxic to fish and aquatic macroinvertebrates. Runoff to waterbodies is a function of the field slope, soil type, water saturation level of the field, time of application, the size of watershed, and amount and intensity of rainfall. Also, the movement of pesticide-containing sediments off field to waterbodies is affected by the nature of the drainage channel (e.g., grassy waterways vs bare soil).

This ecological risk assessment will review all available information concerning these potential exposure pathways, especially field evidence of exposure to fish and wildlife species via these pathways.

3. Analysis--Terrestrial Ecosystems

The Analysis section of the ecological risk assessment for terrestrial ecosystems will summarize relevant information on the exposure and effects of THIMET® to wildlife and the factors that influence exposure and effects. This synthesis will provide a summary of the results from studies that are relevant to this assessment without addressing the uncertainties. A discussion of uncertainties in the data and the implications to characterizing risk will be presented in Sections 4.1.2 and 4.2.2 of the Risk Characterization.

3.1. Characterization of Exposure

3.1.1. Availability of granules

The USEPA (1992b) presented the following formulas for determining the amount of active ingredient exposed on the field surface for 14 granular pesticides:

a) Product per square foot:

$$\frac{\text{Product (oz per 1000 ft of row) x 28,349 mg/oz}}{\text{1000 ft x Band width (ft)}} = \text{Product (mg)/ ft}^2$$

b) Active ingredient per square foot:

$$\text{Product (mg)/ ft}^2 \text{ x \% active ingredient} = \text{active ingredient (mg)/ ft}^2$$

$$\text{Active ingredient (mg)/ ft}^2 \text{ x \% unincorporated} = \text{exposed active ingredient (mg)/ ft}^2$$

The above calculations focus on the exposed active ingredient found within the furrows or bands only, not the entire field area. One of the stated assumptions in the Granular Analysis (USEPA 1992b) is that "calculations were based upon the treated row, since it is the most disturbed area in the field and the focus of bird foraging activity." The assumption that birds primarily focus feeding on the seed row is not supported by experimental data, yet it has a significant impact on the exposure calculations.

However, this disturbance along the seed row will quickly become less distinguishable due to the action of sun, wind, and rain.

An important component of determining the "exposed" active ingredient per unit area is estimating the percentage of granules remaining on the surface after application. USEPA (1992b) cited the work of Hummel (1983) which estimated that approximately one percent of granules remain on the surface after an in-furrow application compared to an average of 15% unincorporated after banded applications (Erbach and Tollefson 1983). Current T-band applications are a cross between in-furrow and older banded application methods, which probably results in less than an average of 15% unincorporated granules.

Based on the above equations and assumptions, the maximum amount of phorate (based on the THIMET® 20G) per square foot on the field surface for each crop can be estimated (Table 3).

The label application rate of THIMET® 20G for all pests in corn is 6 ounces (oz) per 1000 feet of row for any row spacing, but the total THIMET® used is not to exceed 6.5 pounds per acre or 1.3 pounds active ingredient per acre. Consequently, row spacing of less than 30 inches would require use of less than 6 oz per 1000 ft to keep total use at or below 6.5 pounds THIMET® per acre. For 7-inch banded applications, assuming a maximum rate of application for 20G formulations and 15% of granules unincorporated, the exposed active ingredient per square foot of row is 8.75 mg.

Consequently, a source of considerable uncertainty in risk assessments may be introduced by using the average values from Erbach and Tollefson (1983) rather than available data for a particular pesticide formulation. It is likely that the specific characteristics of the pesticide granule will affect how they flow through the application equipment and mix with the soil.

The USEPA has expressed concerns about the turn row areas in fields where the planting equipment pulls out of the soil at the end of a row, potentially spilling a small amount of pesticide if the planter does not shut off the flow of granules prior to pulling out of the soil. There also are concerns for wildlife exposure from pesticide spills at the locations where planter equipment is filled. The LOCK'n LOAD® delivery system greatly reduces the possibilities of field spills at the field margins by using refillable containers that only open when attached to the planter equipment.

Table 3. Estimated milligrams of active ingredient and number of THIMET® 20G granules exposed per square foot of crop row by crop type and time of application.

Crop	Application method	Application time	Application rate (oz/ 1000 ft)	Treatment width (inches)	Total mg/ft^2	Proportion unincorp	Exposed mg AI/ft^2
Beans	In-furrow	At planting	9.4	1	3198	0.01	6.40
	Banded	At planting	7	6	397	0.15	11.91
Corn	Banded	At planting/ cultivation	6	7	292	0.15	8.75
Cotton	In-furrow	At planting	9	1	3062	0.01	6.12
	Side dress	At cultivation	12	3	1361	0.15	40.82
Peanuts	In-furrow	At planting	5.5	1	1871	0.01	3.74
	Banded	At pegging	11	15	249	0.15	7.48
Potatoes	Banded	At planting (sand)	11.3	6	641	0.15	19.22
	In-furrow	At planting (sand)	11.3	1	3844	0.01	7.69
	Banded	At planting (clay)	17.3	6	981	0.15	29.43
	In-furrow	At planting (clay)	17.3	1	5885	0.01	11.77
Sorghum	Banded	At planting	6	7	292	0.15	8.75
	Banded	At cultivation	6	7	292	0.15	8.75
Soybeans	In-furrow	At planting	9	1	3062	0.01	6.12
	Banded	At planting	9	7	437	0.15	13.12
Sugar beets	In-furrow	At planting	4.5	1	1531	0.01	3.06
Wheat	In-furrow	At planting	1.2	1	408	0.01	0.82

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The USEPA has expressed concerns about the turn row areas in fields where the planting equipment pulls out of the soil at the end of a row, potentially spilling a small amount of pesticide if the planter does not shut off the flow of granules prior to pulling out of the soil. There also are concerns for wildlife exposure from pesticide spills at the locations where planter equipment is filled. The LOCK'n LOAD® delivery system greatly reduces the possibilities of field spills at the field margins by using refillable containers that only open when attached to the planter equipment.

3.1.2. Comparison of granules of THIMET® with avian grit selection

Although availability of granules and active ingredient is important to determine exposure potential, avian behavior in selecting food and grit also is important for evaluating potential exposure from intentional ingestion of granules. Best (1992) described the degree of overlap in size, shape, and texture characteristics of grit particles found in several bird species that use corn fields with the same characteristics of THIMET® 20G (Table 4). The degree of overlap of these characteristics gives some insight into those species with the greatest potential to ingest granules with the characteristics of THIMET® (Best 1992). Also, the information on the median count of grit particles in the gizzard and the frequency of occurrence of grit gives insight into which species have the greatest potential to ingest granules, either intentionally or accidentally, based on their intensity of grit use. Based on the data presented by Best and Gionfriddo (1991b), the house sparrow is an intense user of grit and uses grit of similar size to THIMET®. However, Best and Gionfriddo (1991a) concluded that particles that break down rapidly, such as clay granules, probably do not function well as grit and do not provide the tactile stimulus in the gizzard typical of grit. It is not clear if clay granules would be rejected if birds used visual cues or tactile cue in the mouth to identify adequate grit particles. Consequently, even though the size and shape of granules of THIMET® overlaps significantly with the grit particles used by many birds, these may or may not be viewed by birds as adequate grit.

Table 4. Comparison of the percent of gizzards containing grit and the median count and size of grit particles in gizzards of several corn field bird species (from Best 1992).

Species[1]	Number of gizzard samples	Percent of gizzards w/ grit	Median count of grit particles	Median size of grit (mm)[2]
Red-headed woodpecker	22	41	1	0.6
American robin	35	49	0	0.6
Brown-headed cowbird	52	75	6	0.6
Common grackle	45	58	1	0.7
House sparrow	77	99	69	0.7
Chipping sparrow	20	95	7	0.8
Vesper sparrow	59	90	8	0.8
Northern cardinal	20	70	5	0.9
Indigo bunting	20	80	4	0.9
Savannah sparrow	24	100	22	0.9
Red-winged blackbird	53	74	2	1.0
Horned lark	69	99	8	1.1
European starling	39	38	0	1.1
Blue jay	20	85	15	1.2
Northern bobwhite	44	96	12	1.6
Killdeer	25	96	5	1.7
Mourning dove	21	86	10	1.8
Ring-necked pheasant	22	100	38	2.0
American crow	34	59	2	3.4

[1] Gizzards of Eastern kingbird, barn swallow, and dickcissel were also examined, but the frequency of grit and number of particles was too low to determine size, shape and texture information.

[2] Median size of granules of THIMET® 20G is 0.6 mm.

3.1.3. Fate of phorate in the terrestrial environment

Phorate begins to metabolize rapidly in the soil, first by oxidation to phorate sulfoxide (CL 18,177) and then to phorate sulfone (CL 18,161) (Figure 2). Both are more water soluble than phorate and have insecticidal activity (Harris and Chapman 1980). Moisture in the soil removes phorate from the granules and disperses phorate in the soil where it degrades. A study of aerobic soil metabolism on a sandy loam soil demonstrated that phorate degrades with a half-life of 3 days (MRID 40077301). The half-life of phorate sulfoxide was calculated to be 75 days.

$$(C_2H_5O)_2\overset{\overset{O}{\|}}{P}SCH_2SC_2H_5 \rightarrow (C_2H_5O)_2\overset{\overset{O}{\|}}{P}SCH_2\overset{\overset{O}{\|}}{S}C_2H_5 \rightarrow (C_2H_5O)_2\overset{\overset{O}{\|}}{P}SCH_2\underset{\underset{O}{\|}}{\overset{\overset{O}{\|}}{S}}C_2H_5 \rightarrow\rightarrow CO_2$$

Phorate | Phorate Sulfoxide | Phorate Sulfone

Figure 2. Primary degradation products of phorate.

A similar study by Harris and Chapman (1980) found that phorate is rapidly degraded in sand, with 95% removal within four weeks. The maximum amounts of phorate sulfoxide and phorate sulfone detected were 25% and 35% of the applied dose, which were detected at two and five weeks after treatment, respectively. In sand treated with phorate sulfoxide, the sulfoxide was rapidly degraded to phorate sulfone. At 48 weeks after treatment, none of the dose was present as phorate, 0.7% as phorate sulfoxide, and 6.5% as phorate sulfone. In sand treated with phorate sulfone 48 weeks after treatment, none of the dose was present as phorate or phorate sulfoxide and 3.6% was phorate sulfone. Similar results were found in muck soil, except that the conversion of phorate to phorate sulfoxide and phorate sulfone was more rapid than in sand.

Several field dissipation studies in various soil types and conditions demonstrate the factors affecting the rate of phorate degradation. Chapman et al. (1982) found that microorganisms play an important role in the degradation of phorate and its oxidative products. While degradation of phorate is rapid in microbially-active soils, when phorate is applied to sterile soils, the conversion to phorate sulfoxide was much slower and there was no further oxidation to the sulfone.

Phorate applied at 1.0 lb AI/acre as a banded treatment on corn grown in sandy loam soil (1.9% organic matter) degraded rapidly with a half-life of 2 days (MRID 40432001). The half-life of the total residues (i.e., phorate, phorate sulfoxide and phorate sulfone) was seven days. Residues were not detected below six inches in the soil column, except at a sampling immediately after application when granules may have been pushed through the soil profile by the soil sampler.

Phorate applied at 1.3 lb AI/acre as a banded treatment on corn grown in silt loam soil (3.5% organic matter) degraded with a half-life of 19 days. The half-life of the total residues (i.e., phorate, phorate sulfoxide and phorate sulfone) was 117 days. Residues were not detected below three inches, except for the sulfone at the 0.05 ppm detection limit 90 days after treatment.

Phorate applied at 3.0 lb AI/acre as an in-furrow treatment of peanuts grown in sandy loam soil (0.9% organic matter) degraded with a half-life of 39 days. The half-life of the total residues (i.e., phorate, phorate sulfoxide and phorate sulfone) was 45 days. Residues were not detected below 18 inches in the soil column.

Phorate applied at 6.6 lb AI/acre as an in-furrow treatment of peanuts, followed by an application at pegging of 13.2 lb AI/acre (i.e., total application of 19.8 lb AI/acre), grown in sandy loam soil (1.2 % organic matter) degraded with a half-life of 12 days. The half-life of the total residues (i.e., phorate, phorate sulfoxide and phorate sulfone) was 21 days. Residues were not detected below 12 inches in the soil column.

Phorate applied at 15.7 lb AI/acre as an in-furrow treatment of potatoes grown in loam soil (2.2% organic matter) degraded with a half-life of 28 days. The half-life of the total residues (i.e., phorate, phorate sulfoxide and phorate sulfone) was 31 days. Residues were not detected below 12 inches in the soil column.

The results of the field dissipation studies indicate that residues of phorate and its oxidative products remain in the top of the soil profile and do not significantly leach. In most studies, the residues remain in the top six inches of the soil, with only an occasional detection in the 6-12 in layer. It was only in a sandy loam soil with 0.9% organic matter that residues were detected in the 12-18 inch layer. Consequently, phorate or its degradates are not expected to be detected in groundwater because of its rapid degradation including hydrolysis. Phorate was not found in ground water monitoring samples as reported in the USEPA national summary, Pesticides in Ground Water, 1971-1991.

When soils are flooded and anaerobic conditions are formed, the rate of degradation of phorate is slower than under aerobic conditions, with a half-life of 30 days. After three days of aerobic aging, 48% of the applied dose was present as phorate, 36% as phorate sulfoxide, and only 2% as carbon dioxide. During two months of anaerobic aging, 33% of the dose was converted to carbon monoxide.

Phorate also is photodegraded on soil surfaces, with a half-life of approximately two days. The major product formed was phorate sulfoxide, with only small amounts of the sulfone formed.

3.2. Characterization of Ecological Effects

3.2.1. Laboratory toxicity tests

Phorate is considered to be highly toxic based on acute oral toxicity tests (Table 5). Hill and Camardese (1984) found that technical grade phorate was significantly more toxic to bobwhite (*Colinus virginianus*) than the 15G formulation (LD_{50} of 7 vs 21 mg/kg).

Balcomb *et al.* (1984) dosed house sparrows (*Passer domesticus*) and red-winged blackbirds (*Agelaius phoeniceus*) with THIMET® 15G and observed no mortalities in birds given a single granule. Five granules did not kill any of the five sparrows, but killed 3 of 5 blackbirds. Ten granules killed 4 of 5 blackbirds. The calculated LD_{50} for THIMET® 15G was 1.0 mg/kg, which is equivalent to the LD_{50} determined by Schafer (1972) for technical grade phorate.

Dietary toxicity of phorate ranges from LC_{50} values of 248 to 575 ppm in avian species (Table 6). The dermal toxicity of phorate ranges from 2.5 mg/kg in rats to 30 mg/kg in guinea pigs (Table 6). Dermal exposure of THIMET® 15G to rabbits is highly dependent on whether granules are applied wet or dry, ranging from 99 mg/kg wet to 1360 mg/kg dry.

Little toxicity testing has been conducted on the degradates phorate sulfoxide and phorate sulfone. Harris and Chapman (1980) found that the degradates were more toxic than phorate when applied topically to crickets. However, they were less toxic than phorate when crickets were exposed to treated soils. In 90-day feeding studies with rats, phorate sulfoxide was found to be more toxic than phorate (i.e., LOEL of 0.80 ppm vs 2 ppm). Neither the sulfoxide or sulfone are expected on the granules, but are primarily formed after the release of phorate into the soil matrix.

Table 5. Acute oral toxicity of phorate to terrestrial wildlife.

Test species	Age	Grade/ Product	LD_{50} (mg AI /kg)	LD_{50} 95% CI (mg AI /kg)	Reference
Rat	Adult male	90% tech	3.7		Smith 1993
	Adult female	90% tech	1.6		Smith 1993
Northern bobwhite	Adult	tech	7	4-11	Hill and Camardese 1984
	Adult	15G	21	14-31	Hill and Camardese 1984
	Adult	20G	20	16-25	Fletcher and Pedersen 1988a
Chukar	Juv.	98.8% tech	12.8	3.2-51.2	Tucker and Crabtree 1970
Ring-necked pheasant	3-4 month	98.8% tech	7.12	4.94-10.3	Tucker and Crabtree 1970
Mallard	3-4 month	98.8% tech	0.616	0.367-1.03	Hudson et al. 1984
	12 mo.	88% tech	2.55	2.02-3.21	Hudson et al. 1984
	Adult	20G	5.1	4.36-5.96	Fletcher and Pedersen 1988b
Ringed turtledove	Adult	15G	17	9-34	Hill and Camardese 1984
Red-winged blackbird	Unk	Unk	1.0	0.56-1.8	Schafer 1972

Avian reproduction tests were conducted with bobwhite and mallards using technical grade phorate (Wildlife International 1986a, b). Both studies fed the birds diets with phorate at 0, 5, 20, or 60 ppm active ingredient. No treatment-related effects were observed on the bobwhite during the 21-week test except there was a reduction in food consumption observed in the 60 ppm treatment during the first week of treatment. The NOAEL for bobwhite was >60 ppm phorate. In the mallard study, no treatment-related effects were observed at the 5 ppm dietary concentration. A slight effect on adult body weight was observed at 20 ppm, and a significant effect on adult body weight and feed consumption was observed at 60 ppm. At 20 ppm there seemed to be a slight effect on the number of viable embryos as a percent of eggs set. There was a significant effect on reproductive performance at 60 ppm. Consequently, the NOAEL was 5 ppm phorate, with a LOAEL of 20 ppm.

Table 6. Dietary and dermal toxicity of phorate to terrestrial wildlife.

Test species	Age	Purity/ grade	LC_{50} (ppm)	LC_{50} 95% CI (ppm)	Reference
Japanese quail	14 d	90%	575	483-699	Hill and Camardese 1986
Northern bobwhite	14 d	90%	373	326-431	Hill et al. 1975
Ring-necked pheasants	10 d	90%	441	381-510	Hill et al. 1975
Mallard	10 d	90%	248	198-306	Hill et al. 1975
Rat (dermal)	Unk	tech	2.5-6.2 mg/kg		Worthing 1979
Guinea pig (dermal)	Unk	tech	20-30 mg/kg wet		Worthing 1979
Rabbit (dermal)	Unk	15G	99 mg/kg[1]		Meister 1996
	Unk	15G	1360 mg/kg[2]		Meister 1996

[1] Value represents 24-hour continuous exposure to wet paste.
[2] Value represents contact to dry granules.

3.2.2. Field and simulated field studies

One field and several outdoor pen studies have been conducted to address specific questions related to the effects of THIMET® on wildlife under operational or simulated applications (Table 7). These studies, along with other studies on factors affecting avian exposure to pesticide granules (Best 1992, Best and Gionfriddo 1991a & b, 1994), have been instrumental in refining the assessment of risks to wildlife from the use of THIMET®. Given the magnitude and complexity of many of these studies, only brief synopses of the studies will be provided below, but specific items relevant to addressing the assessment endpoints will be described in more detail in the section on Risk Characterization.

Table 7. Field and simulated terrestrial field studies of THIMET®.

Year	MRID No.[1]	Title
1981	Accession No. 245263	THIMET soil and systemic insecticide: Simulated field study with bobwhite quail.
1987	401659-01S	An evaluation of the effects of THIMET® 20-G upon terrestrial wildlife species under actual field use conditions.
1995	Dieter et al.	Effects of phorate on ducklings in northern prairie wetlands.

[1] Author's name if USEPA MRID number is not applicable.

Simulated corn field studies (ACC# 245263)

A series of four related simulated field studies was conducted to determine the potential effects of THIMET® 20G on bobwhite in corn fields. Bobwhite were housed in field enclosures (50 ft x 300 ft) that included a cover area (50 ft x 20 ft) of alfalfa and natural grasses along one border. Treatments of THIMET® were applied at planting, at cultivation, or over the top of plants. Birds fed on food available in each plot for the first three days. Beginning on the fourth day, a mixed grain supplement was scattered in the turn row area of each plot. The bobwhite in all plots were observed daily for mortality, signs of toxicity and abnormal behavior. Birds were periodically collected for determination of brain cholinesterase activity.

In the first study, THIMET® 20G was applied at planting at a rate of 12 oz/1000 ft to two enclosures, but not to a concurrent control enclosure (Wildlife International 1981). Immediately following application, one of the two enclosures was irrigated with 0.5 inches of water. No bobwhite died in the control plot during the 14-day observation period, but one of 30 birds died in the irrigated plot and six of 30 died in the non-irrigated plot. Brain cholinesterase activity of birds in treated enclosures was depressed by 3 to 5% at day 14. Two dead field sparrows were found and were believed to have died of electrocution (from fencing around plots). Of all the dead quail and sparrows found during the study, none contained measurable concentrations of phorate or related compounds in their gastrointestinal tracts (Bohn 1981).

In the second study, THIMET® 20G was applied at cultivation at a rate of 12 oz/1000 ft to two enclosures, but not to a concurrent control enclosure (Wildlife International 1981). Immediately following application, one of the two enclosures was irrigated with

0.5 inches of water. Two of 30 bobwhite died in the control plot during the 14-day observation period, six of 30 birds died in the irrigated plot, and nine of 30 died in the non-irrigated plot. Brain cholinesterase activity of birds in treated enclosures was depressed by 4 to 5% at day 14.

In the third study, THIMET® 20G was applied over the corn whorls at rates of 6 or 12 oz/1000 ft to the two enclosures (Wildlife International 1981) previously treated with THIMET® at cultivation (see the second study). A concurrent control enclosure was untreated. Two of 60 bobwhite died in the control plot during the 14-day observation period, four of 60 birds died in the 6 oz/1000 ft plot, and three of 60 died in the 12 oz/1000 ft plot. Brain cholinesterase activity of bobwhite in the treated enclosures decreased up to 5 days after treatment (42-46% for 6 oz/1000 ft and 63% for 12 oz/1000 ft), but increased by day 14.

In the fourth study, THIMET® 20G was applied at planting at a rate of 6 or 12 oz/1000 ft to two enclosures (Wildlife International 1981). A concurrent control enclosure was untreated. Two of 60 bobwhite died in the control plot during the 14-day observation period, six of 60 birds died in the 6 oz/1000 ft plot, and seven of 60 died in the 12 oz/1000 ft plot. Among birds in the treated enclosures, the degree of reduction of brain cholinesterase activity was greater on day 5 of the treatment period than during day 1 or 14.

This set of simulated field studies demonstrated that the use of THIMET® 20G on corn could result in avian mortality, with sublethal exposure observed throughout the 14 day observation period. These studies may represent worst case exposures since most of the applications were made at 12 oz/1000 ft, a rate that is twice the label rate for corn. Also, the supplemental feeding was done in the turn row area near the alfalfa cover, which concentrated bobwhite activity in the portion of the field with the highest density of exposed granules. Few circumstances in the field will cause such concentrated and prolonged exposure. **The THIMET® Registration Standard summarizing this set of simulated field studies concluded that "based on the results of these studies, there should be no adverse incremental risk associated with the use of THIMET 20-G by application methods and rates in the proposed label."**

Field study in corn (MRID 401659-01S)

Dingledine and Jaber (1987) conducted a terrestrial field study of the effects of THIMET® 20G on corn fields in Maryland. Eight fields were treated with 6.5 pounds of THIMET® per acre at planting in bands (i.e., 6 oz per 1000 feet of row or 1.3 pounds phorate per acre). Four of the fields were treated with ground equipment at cultivation about five weeks after planting with 6.5 pounds of THIMET® per acre. The other four fields were treated by an aerial application of 5 pounds THIMET® per acre (i.e., 1 pound phorate per acre) about eleven weeks after planting. (NOTE: Aerial applications are no longer on the THIMET® label.) No control fields were used in this study.

Surveys of bird populations were conducted for several days before and after each application. **The surveys did not show consistent increases or decreases in the total number of birds, bird species, or number of singing males before and after any of the applications.**

Systematic carcass searches were conducted in the fields and field edges after all applications. Casualty searches following the planting application covered approximately 150 acres over the eight fields. Two dead birds (an adult peacock, *Pavo cristatus*, and a starling, *Sturnus vulgaris*) and a raccoon (*Procyon lotor*) were found on treated fields. Residues of phorate and its cholinesterase-inhibiting metabolites were found only in the raccoon, but authors concluded that phorate could not be precluded as a possible cause of death in the two birds.

Casualty searches following the cultivation application covered approximately 73 acres. Two birds (a great blue heron, *Ardea herodias*, and a starling) and two mammals (shorttail shrews, *Blarina brevicauda*) were found dead. Residues of phorate were not detected in any of the carcasses. The authors concluded that the circumstances did not suggest THIMET® as the cause of death for the birds, but that it could not be precluded as the cause of death of the two mammals.

Casualty searches after the aerial application found six dead birds and two dead mammals. The dead birds were a Carolina chickadee (*Parus carolinensis*), red-winged blackbird , grackle (*Quiscalus quiscula*), indigo bunting (*Passerina cyanea*), American goldfinch (*Carduelis tristis*), and an unknown blackbird, and the mammals were a cottontail rabbit (*Sylvilagus* sp.) and a shorttail shrew. Residue analyses of the whole carcass suggested that THIMET® was the likely cause of death of three of the six birds, although the authors concluded that it could not be precluded as the possible cause of death of the other birds. Although THIMET® was the possible cause of death for one cottontail rabbit, the authors concluded that the circumstances of the death of the shrew were not related to exposure to THIMET® because it was found dead 12 days after application.

In summary, eight corn fields were treated with THIMET® 20G at planting. Four of the fields were treated during cultivation five weeks after planting, while the other four were treated by aerial application 11 weeks after planting. Carcass searches conducted after the two application methods currently in use (i.e., at planting and at cultivation) found a total of seven dead birds and mammals (Dingledine and Jaber 1987). Only one carcass, a raccoon, was found that contained residues of phorate-related compounds. The authors concluded that six other carcasses without detectable phorate residues may have been pesticide-related. All dead animals were found within eight days after treatment. By contrast, carcass searches conducted after the aerial application found six birds and two mammals, with three of the birds containing detectable residues of phorate-related compounds. However, the current label for THIMET® does not support aerial applications.

Simulated wetland/field study

Dieter et al. (1995) conducted a simulated field study of the effects of THIMET® 20G to mallard ducklings in littoral mesocosms in South Dakota wetlands. Four rectangular mesocosms (5.3 x 10.6 m) were constructed along the shorelines in each of three wetlands. Each enclosure had both upland and wetland sections with 5.3 m of shoreline and a maximum depth of 0.8 m. Four treatments were randomly assigned within the enclosures in each wetland—0.0, 1.2, 2.4, and 4.8 kg active ingredient per hectare (i.e., 0, 1.1, 2.1, and 4.3 pounds/acre). Applications of THIMET® were made as a single application by pouring granular product "from a glass container similar to a salt shaker as evenly as possible over the wetland and upland portions." One day after treatment, median concentrations of phorate in the water column were 23, 36, and 45 µg/L in treatments of 1.2, 2.4, and 4.8 kg active ingredient per hectare, respectively. The analytical procedures was not described, so it is unclear if this represents phorate only or all phorate-related compounds. Based on these water concentrations, the application method utilized produced water concentrations that exceed the predicted peak concentrations from the Generic Expected Environmental Concentration Program (GENEEC) model described in Section 5.1. The authors provided no additional information on the decline of the phorate residues or on the sulfoxide or sulfone concentrations.

During the first year, each mesocosm was stocked with eight 21-day-old ducklings, and one of the wetlands was dropped due to an outbreak of *Salmonella* (Dieter et al. 1995). During the second year, each mesocosm was stocked with eight 10-day-old ducklings. The authors reported that 10-day-old ducklings were more sensitive to phorate than the 21-day-old ducklings. All 10-day-old ducklings died within 15 days after treatment while all control birds survived the 30-day test period. Since a large proportion of the ducklings in treated enclosures died within 24 hours, ducklings seem to have received an acutely lethal dose, though it is unclear if the primary route of exposure was consumption of intact granules from soil or sediment or from drinking water. Survival among 21-day-old control birds was poor, but higher than among the 21-day-old birds exposed to THIMET®. Brain and blood cholinesterase activity of the ducklings exposed to phorate was significantly lower than in the control ducklings. Since all current applications of phorate are by ground equipment, it is unclear how direct application of the granules to water in this study models the potential exposure and effects from runoff events.

3.2.3. Wildlife mortality incident reports

A National Agricultural Pesticide Impact Assessment Program (NAPIAP) survey of State and Federal agency personnel was conducted in 1990 to acquire information on wildlife mortalities attributable to THIMET®, as well as other pesticides (Fitzner *et al.* 1990). A total of 154 responses were received from all fifty states, USDA/APHIS/ADC, USFWS, the Cooperative Extension System, and universities. Ten respondents to the

NAPIAP survey reported a total of 11 incidents of nontarget mortality involving phorate: California DOA; California Extension Service; California Fish and Game; Georgia DOA; South Dakota DOA; South Dakota Game and Fish; South Dakota USFWS; South Dakota USDA/APHIS/ADC; Region 6 USFWS; and the Wisconsin Department of Natural Resources. Incidents involved mortalities of songbirds (Passeriformes), waterfowl, gulls, shorebirds, and wading birds (Charadriiformes spp. and Ciconiiformes spp.), upland gamebirds (Phasianidae spp.), mammals, and fish. The timespan between application and mortality ranged from five minutes to six months. Residue analyses were conducted in all 11 incidents, but these results were not reported.

The wildlife incidents involving phorate reported in the NAPIAP survey involved several crops, including wheat (4), alfalfa (2), sugar beets (1), corn (1), and unknown crops (2) (Fitzner *et al.* 1990). The contributing factors associated with these incidents include: runoff after heavy rains (4); runoff from irrigation (2); spilled or partially empty bags left in the field (2); surface application (2); and application in a wetland (1).

A summary of the reported pesticide incidents involving phorate from the Pesticide Incident Monitoring System (USEPA1979) covering the period from the introduction of THIMET® until 1979 did not report any incidents involving wild avian or mammalian species.

A search of the Ecological Incident Information System (EIIS) developed by the Ecological Effects Branch, Office of Pesticide Programs, USEPA, reports 17 records relating THIMET® to a wildlife kill (Table 8). This search was dated 11 September 1995. Many of these incidents overlap with those reported in the NAPIAP survey.

Additional information on the incidents listed in Table 8 helps define the conditions that led to the incident and the role that phorate played in the incident. Beyond the information listed in the table from the EIIS report, the following information also was reviewed for each incident:

- Incident B000150-017: No other information reviewed for this assessment.

- Incident I001476-001: Identified as a case of misuse of phorate in the EIIS report. No other information reviewed for this assessment.

- Incident B000150-014: USEPA reported that ducks and stilts "died in the tail water area of a sugar beet field in Fresno, CA" that had been treated with phorate two days earlier.

Table 8. Summary of wildlife kills for THIMET® as reported from the Ecological Incident Information System of the USEPA Office of Pesticide Programs.

Incident #	Date	State	County	Species[1]	No. killed	Crop	Application method
B000150-017	5/1/91			AR	1	Unk	Unk
I001476-001	12/15/93	BC		BE	5	Unk	Misuse
B000150-014	6/7/72	CA	Fresno	DU, BS	NR	Sugar beet	Soil incorp
B000150-004	11/4/78	CA	Imperial	CE, RG, LC	NR	Alfalfa	Misuse (Aerial)
B000150-005	2/19/81	CA	Fresno	BB, PG, PH	>2000	Wheat	Aerial
B000150-006	2/22/81	CA	Merced	GT, AC, SP, BB, KD, LA	NR	Alfalfa	Misuse (Aerial)
B000150-010	11/4/86	CA	Siskiyou	MA, PI	100	Barley	Unk
B000150-009	1/16/87	CA	Solano	RH	1	Unk	Unk (Not phorate)
B000150-016	5/1/91	GA		BW	8	Wheat	Soil incorp
B000150-011	2/16/87	ID	Jefferson	BE	1	Unk	Unk
B000150-007	10/15/82	SD	Potter	MA, PI, AW, GA, GT, WG, CG, MH, RH, GHO	294	Wheat	Unk (Misuse)
B000150-008	10/16/82	SD	Lyman	MA, GA, AW, PI, GT, RH, GE	66	Wheat	Unk (Misuse)
B000150-012	3/29/89	SD	Hughes	CG, BE, GE, DU, SG	106	Wheat	Soil Incorp
B000150-015	3/29/89	SD	Hughes	GO, DU, SG, BE, SK	104	Unk	Soil Incorp
B000151-001	3/29/89	SD	Hughes	GO, DU	75	Wheat	Soil Incorp
I000504-028	4/5/91	VA	Isle of Wight	AR	1	Unk	Unk
B000150-013	4/7/89	WI	Sauk	MA, CG, BO, HK, SK, OP	74	Unk	Misuse

[1] Species codes: AC = American coot; AR = American robin; AW = American widgeon; BB = blackbird; BE = bald eagle; BO = barn owl; BS = black-necked stilt; BW = bobwhite; CE = cattle egret; CG = Canada goose; DU = unspecified duck; GA = gadwall; GE = golden eagle; GHO = great horned owl; GO = unspecified goose; GT = green-winged teal; HK = unspecified hawk; KD = killdeer; LA = lark; LC = long-billed curlew; MA = mallard; MH = marsh hawk; OP = opossum; PG = pigeon; PH = pheasant; PI = pintail; RH = red-tailed hawk; SG = sharp-tailed grouse; SK = skunk; WG = white-fronted goose.

- Incident B000150-004: Fletcher et al. (1989) reported that THIMET® 10G was aerially applied by helicopter on 4 November, 1978, after renovation and reseeding of alfalfa. The field was recently tilled and under irrigation at the time of application. These conditions attracted large numbers of ring-billed gulls and cattle egrets. Over 175 gulls and egrets were killed, with five gulls and two egrets submitted for diagnosis. "Residue analyses of the proventriculus and gizzard contents showed the presence of Thimet at a level of 150 ppm" based on reports of the Pesticide Investigation Unit, California Department of Fish and Game (Fletcher et al. 1989). Crickets that were presumably regurgitated by gulls contained 92.7 ppm phorate. This incident represented a violation of the pesticide label because the field was under irrigation. The County Agricultural Commissioner suspended the commercial pest control operator's license and revoked his permit to use restricted pesticides for five days. Aerial applications of THIMET® are no longer permitted.

- Incident B000150-005: Fletcher et al. (1989) reported that an aerial application of THIMET® 15G was made on 19 February, 1981, to a wheat field northeast of Mendota, CA. The field had a ditch running along the field and a slough or wet ditch area in the middle of the field. The pesticide application occurred nine days after the wheat field had been reseeded. A rain storm occurred a few days after the reseeding and before the pesticide application. Several days after application, dead birds (2000 blackbirds, 2 pheasants, and several pigeons) were found in the field. A local dog became ill after eating several dead birds, but later recovered. It was diagnosed as having organophosphate poisoning. Six birds were gathered for diagnostic testing, as well as grain samples from the field. Wheat seeds contained no residues of phorate. The birds had no food in their gastrointestinal tracts, but the "gizzard linings" contained 24 ppm of phorate. Although no water samples were taken, investigators from the California Department of Fish & Game and the Fresno County Department of Agriculture concluded that the source of THIMET® was the water in the middle of the field. The State and County agricultural personnel investigating the incident did not consider it a misuse, but aerial applications that could result in direct application to water bodies are no longer permitted.

- Incident B000150-006: Fletcher et al. (1989) reported that THIMET® was aerially applied of 21 February, 1981, to an alfalfa field south of the Russo Gun Club, near Merced, CA. The pesticide was not applied in accordance with label directions. Due to an improperly functioning hopper system on the aircraft, THIMET® was overapplied to the alfalfa field and misapplied to the adjacent areas. Apparently, a large amount of granules was dumped in the waterway around the alfalfa field. One hundred waterfowl, mostly teal, and 100 birds of other species were killed. Phorate residues were present in teal (54 ppm) and coots (31 ppm) and in water and vegetation samples collected 200 yards inside the duck club boundary. The pilot's license was suspended for 22 days and the operator's license was suspended for 10 days.

- Incident B000150-010: Fletcher et al. (1989) reported that dead ducks (50 mallards and 50 pintails) found on 4 November, 1986, at the end of a flooded field that had been previously planted to barley. The diagnosis from the US Fish and Wildlife Service laboratories at Madison, WI, and Patuxent Wildlife Research Center determined the cause of death to be THIMET®. The only known pesticide application had been Di-Syston® in the previous spring. It was not known if THIMET® had been used during the summer. It was known that no pesticides had been used at the site for several months. It was hypothesized that a spill or abandoned bag may have resulted in a hot spot in the flooded field.

- Incident B000150-009: Fletcher et al. (1989) reported that a red-tailed hawk found dead on 16 January, 1987, was not killed by phorate. However, investigators from the State of California were not able to determine the cause of death. This incident should be removed from the phorate list.

- Incident B000150-016: USEPA concluded that the formulation was not THIMET®, but another formulation of phorate. Apparently the equipment used to apply the pesticide "had a tendency to clog because the soil was wet, and upon reaching the turn row, the applicator would lift the planter and whatever was clogged in the drill would spill out onto the ground" (USEPA 1997).

- Incident B000150-011: Fletcher et al. (1989) reported that a bald eagle carcass was sent to the National Wildlife Health Research Center at Madison, WI. The eagle had recently consumed a fatty meal containing wavy white hair. Brain cholinesterase activity was severely depressed. The stomach contents were analyzed with phorate measured at 631 ppm. Fletcher et al. (1989) concluded that this was a deliberate predator control incident.

- Incident B000150-007 and B000150-008: Fletcher et al. (1989) reported that these two incidents occurred at the same time and in the same general vicinity. Numerous dead birds were recovered from pothole ponds in a wheat growing area. In both cases open sacks of THIMET® 15G were found on the pond perimeters. Chemical analysis performed by Patuxent Wildlife Research Center indicated that the white-fronted goose did not die of phorate exposure, but the other birds collected probably died of phorate poisoning. According to Fletcher et al. (1989), the U. S. Fish and Wildlife Service has labeled the incidents as misapplications.

- Incident B000150-012: No other information reviewed for this assessment, although the date, species, and number of individuals are the same or similar to Incident B000150-015 and possibly B000151-001.

- Incident B000150-015. The date, species, and number of individuals are the same or similar to Incident B000150-012 and possibly B000151-001. The USEPA reported that a winter wheat field in Pierre, SD, was treated on September 20, 1988 at an application rate of 1.2 oz/1000 foot row with a 10-inch row spacing (USEPA

1997). "During late winter to early spring, a pond had formed in the wheat field from the thaw of the snow cover and from rain on March 16 and 17, 1989. On March 29, 1989, 70 Canada geese and other waterfowl were found dead around this temporary pond. A few days later, 12 Canada geese, ducks and a sharp-tailed grouse were found dead in a second small pond about one-third mile from the first pond. On March 19, eagles had been observed at one of these ponds feeding on dead geese. Seven bald eagles and possibly one golden eagle are believed to have been fatally poisoned by phorate in this manner" (USEPA 1997).

- Incident B000151-001: No other information reviewed for this assessment, but the date, location, and approximate number and types of birds are the same as Incident B000150-012 and B000150-015.

- Incident I000504-028: Based on the clinical necropsy record of the Southeastern Cooperative Wildlife Disease Study, a robin found dead in a tilled corn field on 5 April 1991 that had been treated with Furadan® 15G on the 4th or 5th. The brain tissue showed a 36% reduction in cholinesterase activity relative to control birds. The gastrointestinal tract contents contained 7.9 ppm phorate, <3.0 ppm carbofuran, and 0.27 ppm DDT. The final diagnosis of cause of death was "organophosphate (phorate/Thimet®) toxicosis suspected." However, the report does not indicate if THIMET® had been used in the area where the bird was found and, if so, the proximity of that use.

- Incident B000150-013: Identified as a misuse in the EIIS report, but no other information reviewed for this assessment.

Of the 17 incident reports in the EIIS report, two (and possibly three) seem to be duplicate reports of the same incident in March, 1989, in Hughes County, SD. Also, incidents B000150-007 and B000150-008 are closely related occurring in the same vicinity in South Dakota at the same time. Seven incidents represent cases of misuse or misapplication; one may have been a spill (B000150-010); and one was determined to be not related to phorate (B000150-009). One incident may have been related to malfunctioning planter equipment in wet soil.

Of the six phorate-related incidents not identified as cases of spills or misuse (assuming the three listed for Hughes County, South Dakota, are the same incident), three occurred in wheat, one in sugar beets, and two did not have a specified crop. The largest bird kill reported (i.e., over 2000 birds in a wheat field in California in 1982) was an aerial application, which is no longer a registered application method.

USEPA reported one additional incident (B000150-018) that was not listed on the EIIS report. This incident involved a bald eagle found near the site of incidents B000150-007 and B000150-008 in South Dakota in 1982. Approximately six weeks after waterfowl kills reported those incidents, an eagle was found with duck parts containing

26 ppm phorate in the gastrointestinal tract—apparently a case of secondary poisoning following those misapplications.

Water is a common element in the majority of the incidents, with mortalities linked to direct application to water bodies, temporary water bodies in treated fields, rainfall producing run-off to water bodies, or equipment malfunctions due to wet soil. Also, the majority of reported incidents occurred from October to March. In some cases, phorate residues have been recovered in carcasses several months after a known application, which is contrary to available data on the half-lives of phorate in soil.

4. Risk Characterization--Terrestrial Ecosystems

The Risk Characterization section of the ecological risk assessment uses the information presented in the Problem Formulation and Analysis sections to describe the likelihood of adverse effects to wildlife occurring as a result of exposure to THIMET® after agricultural applications. The characterization uses information from all sources to evaluate the weight of the evidence.

4.1. Risk Estimation

4.1.1. Integration of terrestrial exposure and effects profiles

There are three general approaches to the integration of exposure and effects profiles to characterize ecological risk: 1) comparing single effect and exposure values; 2) comparing distributions of effects and exposure; and 3) conducting simulation modeling (USEPA 1992a). The *Comparative Analysis of Acute Avian Risk from Granular Pesticides* (USEPA 1992b) describes EPA's use of a risk characterization index that compares single exposure values with single effects values. This index, known as the LD_{50} per square foot (LD_{50}/ft^2), is a dimensionless index calculated from the following input variables: exposed active ingredient per square foot (mg/ft^2); LD_{50} value (mg/kg); and bird weight (kg).

$$LD_{50}/ft^2 = \frac{\text{exposed AI (mg)}/ft^2}{LD_{50}\text{ (mg/kg)} \times \text{bird wt (kg)}}$$

The index is used by USEPA to classify the potential risk for a pesticide use. Fisher (1992) states that the level of concern is exceeded when the LD_{50}/ft^2 index is ≥ 0.5. Initially the Agency set the level of concern at 1.0 based on a 1966 review paper by DeWitt (1966) that compared avian laboratory feeding studies (dietary concentrations converted to mg consumed/bird) with observed field effects for three organochlorine pesticides (DDT, dieldrin, and heptachlor). This critical index level was recently reduced to 0.5 based on more recent work; however, this study is unpublished and has yet to be released to the public. The LD_{50}/ft^2 index has also been used by USEPA in comparative analyses of the risks of alternative pesticide products.

The LD_{50}/ft^2 values calculated for phorate are above the 0.5 level of concern for mallards, bobwhite, and red-winged blackbirds. In corn, an application of 1.3 pounds of active ingredient per acre would result in approximately 8.7 mg of phorate per square foot of row. Based on an LD50 of 1 mg/kg and an average body weight of 52 g for red-winged blackbirds, the LD_{50}/ft^2 value for the 20G product in corn is 168 (Table 9). Based on the lower LD50 value and smaller body weight, the calculated LD_{50}/ft^2 value for red-winged blackbirds is higher in all crops than for mallards and bobwhite (Table 9).

Table 9. Estimated LD_{50}/ft^2 values for mallards, bobwhite, and red-winged blackbirds by crop time and time of application of THIMET®.

Crop	Application time	Appl. rate (ounces/ 1000 ft)[1]	Exposed mg AI/sq ft	LD_{50}/ft^2		
				Mallard[2]	Bobwhite[3]	Red-winged blackbird[4]
Beans	At planting	9.4	6.40	10	5	123
	At planting	7	11.91	18	10	229
Corn	At planting/ cultivation	6	8.75	13	7	168
Cotton	At planting	9	6.12	9	5	118
	Side-dress	12	40.82	61	33	785
Peanuts	At planting	5.5	3.74	6	3	72
	At pegging	11	7.48	11	6	144
Potatoes	At planting (sand)	11.3	19.22	29	15	370
	At planting (sand)	11.3	7.69	11	6	148
	At planting (clay)	17.3	29.43	44	24	566
	At planting (clay)	17.3	11.77	18	9	226
Sorghum	At planting	6	8.75	13	7	168
	At cultivation	6	8.75	13	7	168
Soybean	At planting	9	6.12	9	5	118
	At planting	9	13.12	20	11	252
Sugar beets	At planting	4.5	3.06	5	2	59
Wheat	At planting	1.2	0.82	1	0.7	16

[1] Application rate based on THIMET® 20G.
[2] Mallard LD_{50}/ft^2 based on LD_{50} of 0.62 mg/kg and body weight of 1.082 kg.
[3] Bobwhite LD_{50}/ft^2 based on LD_{50} of 7 mg/kg and body weight of 0.178 kg.
[4] Red-winged blackbirds LD_{50}/ft^2 based on LD_{50} of 1 mg/kg and body weight of 0.052 kg.

The LD_{50}/ft^2 model has several simplifying assumptions that are discussed in the Granular Analysis (USEPA 1992b), including

- the LD50 is the most appropriate laboratory measure of toxicity for estimating acute toxicity of granular pesticides to birds in the field,
- avian exposure to granules is primarily through oral ingestion and the ingestion of granules is primarily accidental (random) rather than selective or intentional,
- risk to birds is primarily from exposed granules rather than those incorporated into the soil,
- the higher the LD_{50}/ft^2 index, the greater the potential risk to birds, although the relationship between the index and avian risk in the field is not known, and
- for in-furrow, banded, and side-dress applications, the index is based on the treated row, since USEPA assumes it is the most disturbed area in the field and the focus of bird foraging activity.

The USEPA recognizes in the Granular Analysis (USEPA 1992b) that there are many other factors that can affect granular risk to birds, but concluded that there was insufficient information at that time to incorporate these factors as generalizable functions that would apply to all birds in all situations. The Agency, however, recognizes that as understanding of exposure patterns increases, methods for characterizing risk will have to be updated.

Under the "new paradigm" used by USEPA for assessing pesticide risks to birds (AEDG 1994), once it has been determined that the risk exceeds the established level of concern (e.g., for granular pesticides when the LD_{50}/ft^2 index is ≥ 0.5), then the risk assessment is to be refined using other pertinent data and risk reduction measures should be identified. The refinement of the risk assessment is most likely done qualitatively rather than quantitatively, because the refinement often is based on factors that are not used in the risk characterization model (i.e., factors other than those in the LD_{50}/ft^2 index). Consequently, the refinement of the risk assessment goes beyond simple preliminary risk indices and weighs the available information in a narrative of the scientific evidence and its associated uncertainties.

For the ecological risk assessment of THIMET®, there are many factors to consider beyond the LD_{50}/ft^2 index in characterizing the risk to fish and wildlife. Also, because the functional relationship between the index and the risk to birds in the field is unknown, **the LD_{50}/ft^2 index can be used to identify pesticide uses with the potential to kill birds, but alone it provides little insight into the potential for widespread and repeated mortalities to birds from the agricultural use of a pesticide product.** Such insight can only be gained through examining the weight of the evidence, including data on calculated exposure, estimates of exposure from biomarker assessment, laboratory toxicity tests, field and simulated field assessments of effects, and fish and wildlife incident reports. The assessment of the weight of the evidence for THIMET® is found in Section 4.2.1 of the Ecological Risk Summary.

The results of laboratory avian reproduction tests are also considered in evaluating the risk of a pesticide to wildlife. The memo by Fisher (1992) states that "for chronic avian tests, the level of concern is reached if the EEC >= LEL." In the avian reproduction studies conducted with mallards and northern bobwhite, there were no reproductive effects observed in bobwhite up to 60 ppm phorate, but reproductive endpoints, including adult food consumption and body weight, were affected significantly at 60 ppm phorate in mallards. A slight effect on adult body weight and number of viable embryos also was noted at 20 ppm. Assuming that an egg-laying female mallard consumes 150 grams per day, 20 ppm is equivalent to a bird consuming 3 mg phorate per day or 167 granules of THIMET® 20G per day. A dose of 3 mg per day for a 1 kg mallard (i.e., dose of 3 mg/kg/day) is higher than the LD_{50} for mallards reported by Hudson et al. (1984) of 0.62 and 2.55 for 3-4 and 12 month old birds, respectively. It also exceeds the LD_{50} for red-winged blackbirds of 1 mg/kg (Schafer 1972).

The USEPA does not have standard procedures for calculating chronic risk quotients for granular products. It is difficult to compare a toxicity value expressed as a dietary concentration with exposure to a pesticide applied as granules in or on the soil. However, effects on reproductive endpoints were not observed until birds consumed daily doses causing parental toxicity. **Studies with other organophosphate pesticides have shown that the observed effects on egg or chick production were largely related to the effects on parental behavior and their reduction in food consumption.** Stromborg (1986a, b) found that reductions in bobwhite egg production were directly related to pesticide-induced reductions in food consumption. **Consequently, it is unclear if the observed effects on mallard reproduction from phorate exposure represents a phenomenon that would occur under field conditions.**

4.1.2. Uncertainty analysis--risk index

There are several sources of uncertainty using the LD_{50}/ft^2 index for assessment of the risks to fish and wildlife from the use of THIMET®, including 1) variability in the point estimates used in the calculation of the risk indices, and 2) uncertainty in relating the laboratory index to risks in the field.

The LD_{50}/ft^2 index is based on several point estimates that all have associated uncertainties. The calculated values in the Granular Analysis (USEPA 1992b) do not reflect the variability in each of the mean or calculated values used. For example, the estimate of the amount of pesticide exposed on the soil surface after a banded application uses an average of 15% for the amount of granules remaining unincorporated, but Erbach and Tollefson (1983) measured a range of 6% to 40%

unincorporated granules. The LD_{50} values also are estimates with associated 95% confidence intervals or, in some cases, the uncertainty around the LD_{50} may not be known. Finally, the bird weights are based on averages of large samples from Dunning (1984), but a measure of the variability in avian body weights is not included in the calculation of the risk index. Consequently, if these sources of uncertainty were factored into the calculation of the LD_{50}/ft^2 index, the point estimate used in deterministic assessments would be a single point in a broad distribution of possible index values.

The LD_{50}/ft^2 index value is the result from a simple model for estimating avian risk from the use of granular pesticides, although its use may expand to flowable formulations as well. Although it assumes that as the index value increases, the risk to birds in the field also increases, the functional relationship between the index and field risk is unknown. There is great uncertainty in interpreting the index if the goal is to estimate that a certain index value equals some level of risk. Similarly, a change in labeling that changes the LD_{50}/ft^2 index value results in an unknown change in the risk to birds. There is also uncertainty using the index to compare among alternative pesticides because of the large number of factors not considered in the LD_{50}/ft^2 index and their potential influence of the comparative risks to birds in the field. Factors such as the material used as the base granule and the size, shape, texture, and pesticide concentration of granules have been shown to influence avian risk in limited studies. Even though these factors could significantly affect the comparison of risks of different products to birds in the field, they are not incorporated into the risk index as it exists today. Consequently, **the risk index has value as a preliminary screening tool, but it is extremely simplistic to rely on the index as a predictor of absolute or comparative risk to wildlife.**

The level of concern value of 0.5 LD_{50}/ft^2 is based on an assessment of many pesticides, but is driven by evidence from one pesticide with characteristics different from THIMET®. The levels of concern for other risk indices (such as the EEC/LC_{50}) are based on establishing a point on a dose-response curve where exposure at a certain level would not be expected to produce unacceptable adverse effects (e.g., one fifth of the LC50 or the NOAEL). The level of concern associated with the LD_{50}/ft^2 index is completely different. It is based on a comparison of field mortalities from granular pesticides with the associated LD_{50}/ft^2 index values for each incident. **Since mortalities were observed in a case with another pesticide where the LD_{50}/ft^2 index was near 0.5, this was established as the level of concern for all pesticides.** Given the number of factors discussed above that can affect granular pesticide risk to birds, but that are not incorporated into the LD_{50}/ft^2 index (e.g., granule material, size, shape and texture), **there is no reason to believe that the level of concern from granules of all pesticides with varying characteristics should be 0.5.** If the reasons for avian exposure to granular pesticides differ among formulations, the relationship between the LD_{50}/ft^2 index and risks to birds in the field would also change. It is very possible that granular pesticide formulations that are selected by birds as grit have a different level of concern relative to the LD_{50}/ft^2 index than formulations that are not selected by birds. This is a source of uncertainty that needs to be discussed further in the development of the use of levels of concern in preliminary risk assessments.

Finally, there is uncertainty about the acute and chronic toxicity of the two primary degradates, phorate sulfoxide and phorate sulfone, to wildlife. A sub-chronic feeding study with rats found that phorate sulfoxide was somewhat more toxic than phorate. However, it is unclear if this is indicative of acute toxicity to birds.

4.2. Risk Description

4.2.1. Ecological risk summary

The LD_{50}/ft^2 index used by USEPA to characterize the risk to birds from THIMET® suggests that a potential for unacceptable risk exists, especially for smaller birds. Evidence from field studies indicates that the use of THIMET® can result in some wildlife deaths based on carcasses found with confirmatory residues of phorate in the gastrointestinal tract and depression of brain and/or plasma cholinesterase activity. However, the focus of this ecological risk assessment is to evaluate the available information to determine if the currently labeled use of THIMET® results in widespread and repeated mortality of birds and other wildlife. This section will focus on the weight of the evidence from the laboratory and field data on the risk of THIMET® to birds and other wildlife.

Based on the laboratory toxicity tests, phorate possesses high acute toxicity to wildlife species tested. For both bobwhite and mallards, the technical phorate was found to be more toxic than the granular products. Consequently, given the high toxicity of phorate, the most important aspect in assessing the risk of phorate to wildlife is to determine if wildlife are exposed to agricultural applications of phorate and, if so, under what conditions and to what extent.

To get a more complete picture of the exposure potential and the types of effects possible in the field, THIMET® has been studied in terrestrial agroecosystems with field and simulated field studies. A field study has been conducted with THIMET® 20G using census counts and carcass searches to identify the species and numbers of animals affected. Simulated field studies with populations of birds confined to areas with granular exposure have been conducted with bobwhite using THIMET® 20G. Several wildlife incident reports, involving cases of both proper use and misuse, also provide information on the conditions that can lead to wildlife poisoning.

In the field study, THIMET® was applied at planting to eight fields and at cultivation and aerially over the whorls to four fields each. **The greatest number of dead birds and mammals were found after the aerial application, a method that has been**

discontinued. Of the two birds and one mammal found on eight fields (150 acres searched) at planting, only the mammal, a raccoon, contained residues of phorate. Similarly, two birds and two mammals were found on four fields (73 acres searched) at cultivation, but none of these contained residues of phorate. The birds found dead on the treated fields provide little insight into the species or feeding patterns at greatest risk. During planting and cultivation applications of THIMET®, two starlings, a peacock, and a great blue heron were found dead. The bird observations during the planting application indicated that 23 of the 71 species identified were observed standing or feeding in the treated fields. Thirteen of the 57 species identified after the application at cultivation were observed standing or feeding in the treated fields. The bird census information did not show a change in bird numbers after application at planting or at cultivation. Overall, this field study provided little evidence that the current application methods (i.e., at planting and at cultivation) used in corn result in substantial adverse effects to birds and mammals.

The series of simulated field studies on corn provide a comparison between irrigated and non-irrigated applications of THIMET® 20G (12 oz/1000 ft of row) at planting and at cultivation. They also provide a comparison of two application rates (i.e., 6 and 12 oz/1000 ft of row) at planting and banded over the top of plants. Since the treatments in each of the four studies were not replicated (i.e., one enclosure per treatment), the results of these simulated field studies should be interpreted with caution. The number of mortalities of captive bobwhite were highest in non-irrigated plots when applied at planting and at cultivation. The number of mortalities may have been lower on the irrigated plot if the irrigation water reduced exposure to phorate by burying granules and/or speeding the movement of phorate from granules and its degradation to oxidation products. The two studies comparing the 6 and 12 oz/1000 ft of row application rates showed no difference in response in the number of quail mortalities or degree of inhibition of cholinesterase activity between the two rates. Also, the number of mortalities in the treated enclosures may not have differed significantly from the control enclosure. Overall, the series of studies demonstrated that under worst-case conditions (i.e., confinement to limited area, supplemental grains distributed in turn rows, and application rates exceeding the label rate for corn) bobwhite will experience increased mortality and inhibition of brain cholinesterase activity. However, it is unclear to what extent this study provides insights into the exposure patterns experienced by free-ranging birds.

The enclosure study by Dieter et al. (1995) was intended to evaluate the risks to juvenile waterfowl in ponds with exposure to granules of THIMET®, which were spread evenly over the upland and wetland portions of the enclosures at three application rates. However, there are no longer aerial applications of THIMET® that would result in the direct deposition of granules into ponds. The concentrations of phorate measured in the water samples from the enclosures one day after application exceeded the concentrations expected from field runoff events (See estimated water concentrations in Section 5.1). Consequently, the study demonstrates that phorate under the conditions of the study is highly toxic to mallard ducklings, but tne conditions simulated in the study would not occur under the application methods currently labeled for THIMET®.

The EIIS of the Office of Pesticide Programs contains reports of phorate-related kills of several mammalian and avian species. However, of the 17 incident reports listed, seven represent cases of misuse or misapplication, one may have been a spill, and one was determined to be not related to phorate. Also, two (and possibly three) seem to be duplicate reports of the same incident in Hughes County, South Dakota. Of the six phorate-related incidents not identified as cases of misuse (assuming the three listed for Hughes County, South Dakota, are the same incident), three occurred in wheat, one in sugar beets, and two did not have a specified crop. Although 95% of THIMET® is used on field and sweet corn, cotton, potatoes, sugarcane, or peanuts, only one of 11 incidents reported in the NAPIAP survey came from one of these crops (i.e., field corn) and none of the 17 terrestrial incidents reported in the EIIS. The largest bird kill reported (i.e., over 2000 blackbirds in a wheat field in California in 1982) was an aerial application, which is no longer a labeled application method for THIMET®. There is not a clear pattern indicating the species at greatest risk, but most of the larger incident reports involved waterfowl or other birds using a water source containing phorate residues. Consequently, **the record of incidents provides little evidence that the use of THIMET® on major crops presents a significant risk of widespread and repeated mortality in conditions under which the product would typically be used.**

Even though the size and shape of granules of THIMET® overlaps significantly with the grit particles used by many birds, there is little evidence that intentional ingestion of granules as grit is the primary exposure pathway. Best (1992) raised the issue that many granule products are similar in size and shape to grit used by birds. Many avian species use a range of grit particles with approximately the same size distribution as granules of THIMET® (Best 1992). THIMET® 20G consists of clay particles that are extremely difficult to see (at least to the human eye) and should not be viewed the same as granular pesticide products based on silica particles. Best and Gionfriddo (1994) found that in comparative trials using house sparrows, a heavy grit consumer, the birds strongly preferred silica particles over all other materials commonly used in granular formulations. The preference for silica particles is probably related to their persistence in the gizzard. Best and Gionfriddo (1991) found that silica particles persisted far longer in the gizzard of house sparrows than other materials used for pesticide granules. **The authors concluded that particles that break down rapidly, such as clay granules, probably do not function as grit and do not provide the tactile stimulus in the gizzard typical of grit.**

Although it is clear that phorate, like a number of commonly used organophosphate compounds, is highly toxic to wildlife and that under some field conditions wildlife will be lethally exposed, the sum of the evidence regarding risks to wildlife from the use of THIMET® suggests that wildlife exposure is variable among individuals and dependent on local conditions. Consequently, the risks to wildlife are variable. The greatest risk from THIMET® may be under conditions where treated fields are temporarily flooded by rainfall or irrigation or where phorate enters shallow waterbodies (e.g., ponds, drainage ditches) during periods of field runoff. Many of the reported wildlife incidents involve exposure to phorate in and around water. In a few cases, phorate residues have been found in carcasses several months after a known application. This implies unrealistic persistence of phorate. The presence of parent months after application indicate that birds may have come into contact with piles of granules where phorate is more stable than in water or soil. The discontinuation of aerial applications of THIMET® significantly reduced the risk of direct application of granules to water bodies. In fact, the majority of reported incidents occurred in the 1980s with the last incident, a known misuse, in 1993. Runoff from agricultural fields or misuse of THIMET® still may result in phorate residues in aquatic systems toxic to both aquatic organisms and water-dependent wildlife.

THIMET® has been used on agricultural crops for over 40 years. During this period the wildlife incident reports related to phorate do not suggest that wildlife mortality is widespread and repeated. **By eliminating those incidents that were cases of misuse and those that involved aerial application, it seems that the currently-labeled ground applications have resulted in few wildlife mortalities and do not indicate a clear pattern of widespread or repeated mortality.**

4.2.2. Uncertainty analysis--field studies

Although Section 4.1.2 detailed the uncertainties associated with the use of the LD_{50}/ft^2 index, the more direct methods of measuring the effects of pesticide applications to birds in the field and estimating risks from empirical data also contain considerable uncertainty. The exposure of individuals is highly variable, depending on the study conditions. Factors such as weather, adjacent wildlife habitats, the use of other agricultural chemical products and crop management practices, and uncertainties in the movement and feeding patterns of wildlife introduce many uncontrollable factors into any field assessment of risk.

Simulated field studies effectively address specific questions and provide evidence on the nature of effects from pesticide exposure to wildlife, but extrapolation of their results to the field must be done with caution. Although attempts are made to create an exposure scenario similar to the field, this can never be done completely. In some cases, the simulated field study tries to create a worst-case scenario by keeping birds confined to treated soils 100% of the time. If the primary risk to birds is through accidental ingestion of granules or consumption of invertebrates containing pesticide residues, both of these exposure pathways are compromised in simulated field studies. The availability of granules is changed by the extra disturbance of the soil in the relatively small pen areas and foraging patterns are modified to the supplemental feeding regime, since insufficient "natural" food exists for the duration of the study. Accidental ingestion of granules would be changed if the availability of granules changes. Ingestion of the pesticide through invertebrate foods is extremely difficult to simulate. The presence of supplemental food also changes the ability of the simulated field test to predict exposure in the field.

In field studies conducted without concurrent control plots, it is difficult to determine if the number of dead animals found during carcass searches reflects only pesticide-related deaths or a combination of causes related to pesticides and other causes. In the field study of THIMET® 20G conducted in corn, many of the carcasses located contained no measurable residues of phorate and died under conditions that suggested other causes of death besides phorate. However, in most cases the cause of death cannot be determined conclusively, creating uncertainty in determining the role of phorate as a cause of death.

Using carcass searching, the number of dead animals found per unit area is a function of the efficiency of the search and the rate of removal of carcasses by scavengers. Although these factors are quantified as part of the carcass searching process, this method contains many uncertainties for estimating the numbers of pesticide-related casualties.

Finally, the use of incident reports in a risk assessment carries many uncertainties. The presence of confirmed incident reports provides positive evidence of the conditions under which pesticide poisonings may occur and some insights into the magnitude of effects if the incident is clearly diagnosed as to its cause and the investigation is well documented. Poorly diagnosed and poorly documented incidents provide more confusion than insight. On the other hand, the absence of incident reports is not always a clear indication that incidents do not occur. Mineau (1988) suggests that incident reports based on voluntary notification of kills provides a biased reflection of the direct lethal effects of granular pesticides to birds, under-representing kills of small, widely dispersed birds such as breeding songbirds. Similarly, Grieg-Smith (1994) cautioned that although incident monitoring is a useful tool as a relative index of problems, it is a weak method for establishing a lack of effects. **To reduce uncertainties in the use of incident reports for ecological risk assessments, it is important to integrate information on incidents with information on expected patterns of exposure, the temporal manifestation of effects observed in laboratory studies, and intensive field experimentation on birds in pesticide-treated fields.**

4.2.3. Interpretation of ecological significance

Although no studies have quantified the precise magnitude of effects to wildlife from the agricultural use of phorate, the available field evidence does not suggest a pattern of widespread and repeated mortality to wildlife. Clearly, phorate is highly toxic to wildlife and, if misused, can result in large die-offs of birds. However, the current ground applications for the major uses of phorate do not have a record of field incidents, and a field study in corn showed little direct evidence of phorate poisoning of wildlife.

Although there does not seem to be a widespread pattern of effects to wildlife from THIMET®, there are site-specific conditions that may lead to acute poisoning of wildlife. The documented field incidents indicate that the greatest risk from THIMET® may be under conditions where treated fields are temporarily flooded by rainfall or irrigation or where phorate enters shallow waterbodies (e.g., ponds, drainage ditches) during periods of field runoff. (Note: The THIMET® label clearly warns "do not apply directly to water or to areas where surface water is present" and "do not contaminate water when disposing of equipment washwaters.") These conditions may also lead to effects on aquatic organisms. However, these effects may be isolated events with little long-term ecological significance.

5. Analysis--Aquatic Ecosystems

The Analysis section of the ecological risk assessment for aquatic ecosystems will summarize relevant information on the exposure and effects of THIMET® to fish and other aquatic organisms and the factors that influence exposure and effects. This synthesis will provide a summary of the results from studies that are relevant to this assessment without addressing the uncertainties. A discussion of uncertainties in the data and the implications to characterizing risk will be presented in Sections 6.1.2 and 6.2.2 of the Risk Characterization.

5.1. Characterization of Exposure

Since THIMET® is applied as a banded or in-furrow granular product by ground equipment during planting and at cultivation, there should be no direct exposure to waterbodies if applied according to label directions. However, phorate has the potential to enter waterbodies via runoff from treated fields. Runoff events are a function of several factors, including 1) rate and frequency of rainfall, 2) tillage practices, 3) slope pattern, 4) watershed size, and 5) soil type.

For phorate that does enter aquatic systems, the solubility is approximately 22 ppm at 25°C. The water solubilities of phorate sulfoxide and phorate sulfone are 8,926 ppm (Mangels and Lucas 1989a) and 734 ppm (Mangels and Lucas 1989b), respectively. These differing solubilities are correlated with different adsorption/desorption coefficients. The K_{oc} of phorate is about 543, categorized as moderately bound to soil. The K_{oc} for phorate sulfoxide and phorate sulfone are 135 (Mangels 1990a) and 117 (Mangels 1990b), respectively.

Chapman and Cole (1982) measured the half lives of phorate, phorate sulfoxide, and phorate sulfone at several pH values. At pH 7, the half lives were 0.57, 25, and 8 weeks, respectively. The half life of phorate remained about the same within the pH range 4.5 to 8, but the half lives of the sulfoxide and sulfone decreased with increasing pH in this range. The results obtained by Chapman and Cole (1982) for phorate are similar to those obtained for phorate by American Cyanamid. The hydrolysis half life is 2.6 to 3.9 days at pH 5 to 9, and the photolytic half life is 1.1 days. The primary degradation product from hydrolysis is formaldehyde (Mangels and Lucas 1989c, 1989d). Consequently, the greatest exposure to aquatic organisms would be from the phorate degradates, the sulfoxide and sulfone. These two compounds are more water soluble, are less strongly bound to soil, and are more persistent in either the soil or water than the parent compound, phorate.

The USEPA frequently uses a deterministic model, known as the Generic Expected Environmental Concentration Program (GENEEC), to estimate the loading of pesticides from field runoff to water bodies such as ponds. GENEEC calculates an acute and chronic expected environmental concentration of the dissolved pesticide in water. The model considers reduction in dissolved pesticide concentration due to adsorption of pesticide to soil or sediment, soil incorporation, degradation in soil before wash off to a water body, and degradation of the pesticide within the water body. The Aquatic Risk Assessment and Mitigation Dialogue Group (1994) described a four-tier system of aquatic exposure and risk assessments. The GENEEC approach, relative to this proposed system, would constitute a Tier 1 worst-case assessment. Higher tier analyses would consider geographic variation in rainfall, soils, and slopes, and potential mitigation measures, such as buffers (Aquatic Risk Assessment and Mitigation Dialogue Group 1994). GENEEC is a first tier model and is designed to mimic a PRZM-EXAMS simulation. The estimated environmental exposure concentration (EEC) is calculated at peak concentration and at 4, 21, and 56 days after initial exposure.

Based on a one-time maximum application rate of 1.3 pounds THIMET® per acre, granule incorporation of 2 inches (e.g., banded with incorporation), soil K_{oc} of 543, a water solubility of 50 ppm, an aerobic soil metabolic half-life of 3 days, and a photolysis half-life of 1 day, the GENEEC model predicts a peak environmental concentration of 7.83 µg/L (ppb) and average concentrations of 5.61, 1.70, and 0.64 µg/L at 4, 21, and 56 days, respectively. An incorporation depth of 1 inch for in-furrow applications (based on GENEEC options) results in a peak environmental concentration of 15.66 µg/L and average concentrations of 11.22, 3.39, and 1.28 µg/L at 4, 21, and 56 days, respectively.

The factor most critical to the calculation of the EEC is the estimate of percent runoff. In the field, the proportion of the chemical that is lost as runoff may vary from none to several percent. If there are no runoff events during a year, there will be no pesticide leaving the field via water, and thus no risk to aquatic organisms. When runoff does occur with granular pesticide products, the loss rate is usually less than 0.5% (Wauchope 1978). Runoff losses of 2% or higher were considered to be catastrophic events (Wauchope 1978).

5.2. Characterization of Ecological Effects

5.2.1. Acute toxicity

The 96-hour LC_{50} has been calculated for several freshwater and marine fish and aquatic invertebrates (Table 10), including rainbow trout (*Oncorhynchus mykiss*), cutthroat trout (*Oncorhynchus clarki*), largemouth bass (*Micropterus salmoides*), bluegill sunfish (*Lepomis macrochirus*), channel catfish (*Ictalurus punctatus*), northern pike (*Esox lucius*), walleye (*Stizostedion vitreum*), spot (*Leiostomus xanthrus*), sheepshead minnow (*Cyprinodon variegatus*), longnose killifish (*Fundulus similis*), scud (*Gammarus* *fasciatus* and *lacustris*), crayfish (*Oronectes nais*), stonefly (*Pteronarcys californica*), white shrimp (*Penaeus stylirostris*), pink shrimp (*Penaeus duorarum*), mysid shrimp (*Mysidopsis bahia*), and brown shrimp (*Penaeus aztecus*). Most of the studies with technical phorate have LC_{50} values classified as very highly toxic. The 96-hour LC_{50} values using THIMET® 20G were higher than technical phorate (Table 11), although studies on technical phorate were conducted with flow-through methods while the granular product was tested with static-renewal methods.

5.2.2. Chronic toxicity

A 21-day life cycle toxicity study of phorate to *Daphnia magna* was conducted under static renewal conditions (Yurk and Wisk 1992). The measured exposure concentrations of phorate in water were 0, 0.09, 0.21, 0.41, 0.84, and 1.81 µg/L. The 21-day LC50 for immobilization was 0.72 µg/L (95% confidence interval of 0.41 to 0.84 µg/L). The Maximum Acceptable Toxicant Concentration (MATC) during the complete life-cycle based on survival and growth was 0.59 µg/L and the NOEC was 0.41 µg/L.

A 21-day life cycle toxicity study of phorate to *Daphnia magna* was conducted under flow-through conditions (Springborn Bionomics 1986a). The measured exposure concentrations of phorate in water were 0, 0.12, 0.29, 0.44, 0.82, and 1.9 µg/L. The MATC of phorate during the complete life-cycle based on survival was 0.36 µg/L.

Rainbow trout embryos and larvae were continuously exposed to phorate for 88 days (Springborn Bionomics 1986b). The mean measured concentrations were 0, 0.22, 0.47, 1.1, 1.9, and 4.2 µg/L. Based on the most sensitive endpoint of larval growth, the MATC was 2.8 µg/L.

Sheephead minnow embryos and larvae were continuously exposed to phorate for 35 days (Sousa 1991a). The mean measured concentrations were 0, 0.016, 0.020, 0.047, 0.096, and 0.19 µg/L. Based on the most sensitive endpoints of survival at hatch and larval growth, the MATC was estimated >0.096 µg/L and < 0.19 µg/L (geometric mean MATC = 0.14 µg/L).

A 28-day life cycle toxicity study of phorate to mysid shrimp was conducted under flow-through conditions (Sousa 1991b). The measured exposure concentrations of phorate in water were 0, 0.0055, 0.0099, 0.022, 0.044, and 0.093 µg/L. Based on the number of offspring produced per day, the MATC of phorate during the life-cycle was >0.0055 µg/L and <0.0099 µg/L (geometric mean MATC = 0.0074 µg/L).

Table 10. 96-Hour LC_{50} (µg/L and 95% confidence intervals) of phorate to fish and aquatic invertebrates.

Species	Age/Size	% AI	LC50	95% CI	EPA ID #
		FISH			
Rainbow trout	1.2g	100	13	11-16	003503
Rainbow trout	1.0g	100	21	16-27	40098001
Rainbow trout	NA	66	19	14.5-24.3	090490
Cutthroat trout	1.0g	100	66	61-71	40098001
Cutthroat trout	1.0g	100	44	NA	40098001
Cutthroat trout	1.0g	100	340	270-430	40098001
Largemouth bass	0.9g	91	5.0	4.7-5.4	003503
Bluegill sunfish	1.2g	100	3.8	3.1-4.6	40098001
Bluegill sunfish	0.3g	100	1.0	0.6-1.8	40098001
Bluegill sunfish	4.0g	100	4.0	3.5-4.3	40098001
Bluegill sunfish	1.6g	100	2.3	2.0-2.6	40098001
Bluegill sunfish	0.6g	100	2.4	2.1-2.7	40098001
Bluegill sunfish	1.0g	91	2.0	1.5-2.5	003503
Bluegill sunfish	NA	66	<2.8	NA	090491
Channel catfish	1.0g	100	280	115-680	003503
Northern pike	0.7g	100	110	90-130	003503
Walleye	1.4g	100	340	270-430	40098001
Walleye	1.2g	100	57	42-77	40098001
Spot	Adult	90	3.9	3.1-5.6	40228401
Spot	Adult	89.5	5.0	4.2-5.6	40228401
Spot	Juvenile	90	3.2	NA	40228401
Sheepshead minnow	Adult	90	1.3	0.97-1.7	40228401
Sheepshead minnow	Juvenile	90	4.0	3.5-4.5	40228401
Longnose killifish	Juvenile	90	0.36	NA	40228401
		AQUATIC INVERTEBRATES			
Scud	M	100	4.0	2.0-7.0	003503
Scud	NA	Tech	9.0	5.1-13	0097842
Scud	NA	Tech	0.68	0.36-1.0	05017538
Scud	M	Tech	0.6	0.4-0.8	40098001
Crayfish	NA	Tech	50	30-75	05017538
Stonefly	YC2	100	4	2-6	003503
White shrimp	Juvenile	90	0.27	0.18-0.32	40228401
Pink shrimp	Adult	90	0.11	0.08-0.16	40228401
Mysid shrimp	Juvenile	90	0.33	0.27-0.43	40228401
Mysid shrimp	Juvenile	89.5	1.9	1.0-3.2	40228401
Mysid shrimp	Adult	90	0.31	0.22-0.43	40228401
Brown shrimp	Juvenile	90	0.46	NA	40228401

Table 11. 96-Hour LC_{50} (95% confidence intervals) of THIMET® 20G to fish and aquatic invertebrates.

Species	LC_{50} (µg/L)	95% CI (µg/L)	EPA ID No.[1]
Rainbow trout	45	37-57	161822
Bluegill sunfish	12	7.8-13	161823
Channel catfish	2200	1000-4200	161824
Sheepshead minnow	8.2	5.5-10	40001801
Water flea	37	30-44	161825
Midge larvae	41	38-45	161825
Mayfly nymph	65	47-140	161827
Mysid shrimp	1.4	1.2-1.7	40001802
Quahog clam embryo-larvae	17	4.4-71	40004201

[1] All studies conducted by Springborn Bionomics, Inc. with reports submitted in 1986.

Another 28-day life cycle toxicity study of phorate to mysid shrimp was conducted under flow-through conditions (Overman and Wisk 1995). The measured exposure concentrations of phorate in water were 0, 0.0053, 0.0098, 0.0202, 0.0386, and 0.0722 µg/L. Based on the most sensitive endpoint of total length of shrimp, the MATC of phorate during the life-cycle was >0.0053 µg/L and <0.0098 µg/L (geometric mean MATC = 0.0072 µg/L).

A study of the uptake, depuration, and bioconcentration of radio-labeled phorate exposed bluegills to a concentration of 0.10 µg/L for 28 days (Forbis 1987). Daily bioconcentration factors ranged from 56 to 370X, 82 to 630X, and 120 to 740X for fillet, whole fish, and viscera, respectively. Uptake tissue concentrations of phorate ranged from 5.2 to 37 ppb for fillet, 7.6 to 63 ppb for whole fish, and 11 to 74 ppb for viscera. During a 14-day elimination period in clean water, the amount of phorate measured decreased by 87%, 92%, and 91% from fillet, whole body, and viscera, respectively. Whole fish levels decreased from 63 ppb at the end of treatment to 5.0 ppb after 14 days in clean water.

Hussain (1989) reported that the major residues found in bluegills after a 28-day exposure to radio-labeled phorate were the oxidative metabolites, phorate sulfoxide and phorate sulfone. Phorate accounted for less than 2% of the total residues in all samples. In fillets, 25.1% and 22.8% of the residues were the sulfoxide and sulfone, respectively. Similarly, in the whole bodies, residues consisted of 25.0% and 19.5% of the sulfoxide and sulfone. Other major metabolites included the oxygen analogs of the metabolites.

5.2.3. Aquatic field study

An aquatic field study was conducted to evaluate changes in populations of phytoplankton, zooplankton, macroinvertebrates, and fish resulting from terrestrial applications of THIMET® 20G (Krueger and Schneider 1992). The study was conducted using five test ponds with the adjacent watersheds of three ponds (Ponds 3, 4, and 5) treated with THIMET® 20G and two ponds (Ponds 1 and 2) with untreated watersheds. Granules were applied to corn fields near Milo, Iowa, in 7-inch bands (with incorporation) at the rate of six ounces per 1000 feet of row. Two fields planted with 38-inch row spacing had a resulting application rate of 5.1 pounds THIMET per acre (1.0 pounds AI/acre), while the field with 30-inch spacing had an application rate of 6.5 pounds THIMET per acre (1.3 pounds AI/acre). Planting occurred between April 24 and May 11, 1989.

Samples of runoff and pond water were collected after rainfall events large enough to produce runoff into each pond. Consequently, the runoff events varied among fields, but all fields were monitored on May 24 and 29 after two heavy rainfalls in the area. Physical and chemical characteristics of the pond water were also evaluated. The greatest exposure to aquatic organisms would be from the phorate degradates, the sulfoxide and sulfone. These two compounds are more water soluble, are less strongly bound to soil, and are more persistent in either the soil or water than the parent compound, phorate.

Phorate was not detected in any of the runoff samples and in only one sample of pond water from Pond 4. The one sample containing phorate just above the limit of detection was collected on September 25 and may be an analytical anomaly. Mean values of both phorate sulfoxide and phorate sulfone were greatest in the treated ponds during the 13 day period from May 24 to June 5, which included the major runoff events on May 24 and 29. Those runoff events corresponded to large increase in pond volumes and represented the critical times when phorate degradates entered the ponds. Residues of the sulfone and sulfoxide were near the limit of detection in Pond 3 throughout the study, peaked in Pond 4 between May 24 and June 15, and peaked in Pond 5 between May 24 and June 29. Daily mean sulfone concentrations reached their highest values of approximately 0.3, 1.2, and 4.6 ppb in Ponds 3, 4, and 5, respectively. Daily mean sulfoxide concentrations reached their highest value of approximately 0.2, 1.6, and 3.4 ppb in Ponds 3, 4, and 5, respectively. Pond concentrations of sulfoxide and sulfone were positively related to the amount of runoff water entering the ponds.

Several methods were employed to evaluate the population responses of phytoplankton (measures of abundance, chlorophyll a, gross primary productivity, net photosynthesis, and community respiration), zooplankton (enumeration by taxa), macroinvertebrates (enumeration from artificial substrates and emergence traps), and fish (measures of relative condition, fecundity, mortality, and stomach analysis) during the course of the study in relation to runoff events and pesticide residue concentrations.

Overall, there were no apparent treatment-related effects observed on populations of phytoplankton, zooplankton, macroinvertebrates, and fish following applications of THIMET® 20G to fields adjacent to the test ponds (Krueger and Schneider 1992). Fish mortalities were low in all ponds, except one of the treated ponds (i.e., Pond 5). However, the 50 bluegills and approximately 50 fathead minnows found dead on March 13 occurred prior to the pesticide application and soon after the ice melted. Also, the bluegill, bass, and fathead minnows found dead in August (mostly after August 15) were collected more than three months after application when residues of phorate sulfoxide and phorate sulfone were at or near the 0.2 ppb limit of detection. Although the cause of death is unknown, the circumstances of the deaths indicate no direct toxicity from phorate.

5.2.4. Fish and aquatic invertebrate mortality incident reports

A National Agricultural Pesticide Impact Assessment Program (NAPIAP) survey of State and Federal agency personnel was conducted in 1990 to acquire information on wildlife mortalities attributable to THIMET® (Fitzner *et al.* 1990). A total of 154 responses were received from all fifty states, USDA/APHIS/ADC, USFWS, the Cooperative Extension System, and universities. Ten respondents to the NAPIAP survey reported a total of 11 incidents of nontarget mortality involving phorate, however, these involved mostly terrestrial wildlife (See Section 3.2.3). Fitzner *et al.* (1990) mention a incident of dead mosquitofish, but there are no further details.

A search of the Ecological Incident Information System (EIIS) developed by the Ecological Effects Branch, Office of Pesticide Programs, USEPA, found five records listing THIMET® related to kills of fish and other aquatic organisms (Table 12). The two incidents from Nebraska in 1985 seem to be duplicate listings of a case of accidental misuse on milo. The incidents of fish kills in Illinois occurred in farm ponds near recently treated fields that had received rainwater from heavy rainfalls.

The same phorate-related incidents involving mortality to aquatic organisms in Illinois are reported through the Pesticide Incident Monitoring System of the Office of Pesticide Programs (USEPA 1979). Three farm ponds received field runoff after several heavy rainfalls from adjacent corn fields treated with phorate and a variety of other pesticides.

- One pond was one acre in size with a maximum depth of 15 to 18 feet. The pond received runoff water from approximately 20 to 40 acres of an adjacent corn field treated with phorate, isoctyl ester of 2,4-D, and EPTC. Two or three days after a heavy rainfall of 2.5 inches, the farmer reported 30 to 50 dead fish, mostly bluegills and bass. The water was highly turbid and full of soil and field debris. Frogs were active along the shoreline. Water samples indicated phorate concentrations of 6.8

and 8.3 µg/L in the deep end two weeks after the rainfall and 0.4 and 0.5 µg/L about one month later. Although the incident report presents concentrations of phorate in water, it is not clear if this is only phorate or phorate and related residues.

Table 12. Summary of fish kills as reported from the Ecological Incident Information System of the USEPA Office of Pesticide Programs.

Incident #	Date	State	County	Species[1]	No. killed	Crop	Application method
B000150-003	5/1/70	IL	NR	BA, BL	NR	Corn	Unknown
B000150-002	5/2/70	IL	NR	BA, BL, CA, CR, GR, MN, SU, WS	NR	Corn	Unknown
B000150-001	5/3/70	IL	NR	BA, BL	NR	Corn	Unknown
I000598-001	5/17/85	NE	Butler	BA, BL, CA, CR, UN	>2000	Milo	Soil incorp (MISUSE)
I000598-001A	5/17/85	NE	Butler	UN	hundreds	Milo	Soil incorp (MISUSE)

[1] Species codes: BA = bass; BL = bluegill; CA = catfish; CR = crappie; GR = greengill; MN = minnows; SU = sunfish; WS = water snake, UN = unknown.

- A second nearby pond was about two acres with a maximum depth of 15 to 20 feet. The pond received a considerable amount of sheet erosion from approximately 60 acres of corn planted on rolling terrain. The field was treated with phorate and propachlor one day before the heavy rainfall. Two days after the rainfall of 2.5 inches, a variety of dead fish were observed by the farmer, maybe as many as 2,000 to 3,000. The water was reported to be turbid and full of soil and field debris. Frogs were active along the shoreline. Approximately 10 days later, the same farmer found two dead fox squirrels and one dead water snake, but it is unclear from the account if these are related. Water samples collected 15 days after application contained 9.7 to 32.3 µg/L phorate and concentrations of 0.5 to 0.6 µg/L were measured a month later.

- A third pond received runoff water from a field treated with phorate, atrazine, and propachlor. Heavy rains occurred on the fourth and fifth day after planting. The farmer began noticing dead fish (mostly bass and bluegill) in the pond a few days after the rains, with fish continuing to die for the next five to six days. Phorate concentration in the water sample taken 37 days after application was 12.1 µg/L.

Additionally, several fish kill incidents have been reported in recent years by American Cyanamid in 6a2 reports that were not entered into the EIIS report dated 11 September 1995. All incidents occurred in constructed farm ponds when heavy rainfalls (usually greater than 3 inches in 48 hours) fell within a week after planting. Two occurred in Ohio, one in 1992 and one in 1995. Three occurred in one county in Iowa after the same rainfall event.

6. Risk Characterization--Aquatic Ecosystems

The Risk Characterization section of the ecological risk assessment uses the information presented in the first two sections to describe the likelihood of adverse effects to fish and wildlife occurring as a result of exposure to THIMET® after agricultural applications. The characterization uses information from all sources to evaluate the weight of the evidence.

6.1. Risk Estimation

6.1.1. Integration of aquatic exposure and effects profiles

In aquatic systems, risk is also estimated using an index based on point estimates of exposure and effects. The risk index is a quotient of the expected environmental concentration (EEC) divided by a measure of effects, i.e., the LC_{50}. The index is used by USEPA to classify the potential risk for a pesticide use. Fisher (1992) states that the level of concern is exceeded when the EEC/LC_{50} index is $\geq$ 0.5. When the index is between 0.1 and 0.5, then the pesticide is considered for classification as a restricted use pesticide. The index can also be used by USEPA in comparative analyses of the risks of alternative pesticide products.

The LC_{50} values for freshwater fish ranged from 1.0 to 340 µg/L phorate and for freshwater aquatic invertebrates ranged from 0.6 to 50 µg/L phorate. The LC50 values for THIMET® 20G were higher, ranging from 12 to 2,200 µg/L phorate for freshwater fish and from 37 to 65 µg/L phorate for freshwater aquatic invertebrates.

The EEC is calculated using a deterministic model (GENEEC) of the USEPA described in Section 5.1. Based on model estimates, the environmental concentration of phorate in water due to runoff from sites treated with banded applications THIMET® 20G at 1.3 pounds active ingredient per acre would have a peak environmental concentration of 7.83 µg/L (ppb) and average concentrations of 5.61, 1.70, and 0.64 µg/L at 4, 21, and 56 days, respectively. Acute risk indices were calculated using the average of the concentrations on Day 0 and 4 (i.e., 6.72 µg/L). Using the lowest LC_{50} values for freshwater fish, the acute risk index values range from 0.02 for walleye to 6.7 for bluegills (Table 13). Acute risk indices are considerably lower for bluegills, rainbow trout, and catfish when using the LC50 values from tests using THIMET® 20G (Table 14).

Table 13. Acute risk index values (i.e., expected environmental concentration/toxicity) for phorate based on concentrations predicted with GENEEC (average of 7.83 and 5.61 µg/L phorate at peak concentrations and after 4 days, respectively).

Fish	Bluegill	Bass	Rainbow trout	Cutthroat trout	Catfish	Walleye
96-h LC_{50}	1.0	5	13	44	280	340
Acute Risk Index	***6.7***	***1.3***	***0.52***	0.15	0.02	0.02

Table 14. Acute risk index values (i.e., expected environmental concentration/toxicity) for THIMET® 20G based on concentrations predicted with GENEEC (average of 7.83 and 5.61 µg/L phorate at peak concentrations and after 4 days, respectively).

Fish	Bluegill	Rainbow trout	Catfish	Sheepshead minnow
96-h LC_{50}	12	45	2200	8.2
Acute Risk Index	***0.56***	0.15	0.003	***0.82***

The acute risk index values for freshwater invertebrates exposed to technical product ranged from 0.13 for crayfish to 11.2 for scud. Using THIMET® 20G, the acute risk indices ranged from 0.10 for mayfly nymphs to 0.18 for water fleas. The acute risk indices for marine and estuarine invertebrates exposed to phorate all exceeded the EPA level of concern, ranging from 3.54 for mysid shrimp to 61.1 for pink shrimp. Using THIMET® 20G, the acute risk indices were 0.40 for quahog clams and 4.80 for mysid shrimp.

The concentration of phorate estimated by the GENEEC model at 21 days is 1.7 µg/L. This exceeds the MATC for a 21-day exposure to water fleas (*Daphnia magna*) by static renewal (MATC = 0.59 µg/L) and flow through (MATC = 0.36 µg/L) methods. The MATC calculated for rainbow trout after 88 days of exposure to phorate was 2.8 µg/L. This is higher than the EEC at 21 days (Chronic Risk Index = 0.61) and 56 days (Chronic Risk Index = 0.23). The chronic risk indices for marine and estuarine organisms were highest. The EEC of 1.7 µg/L at 21 days is higher than the MATC of 0.14 µg/L for sheepshead minnows exposed to phorate for 35 days and of 0.0072 µg/L for mysid shrimp exposed for 28 days.

According to Fisher (1992), if a risk exceeds the level of concern, the risk assessment should be refined using approaches such as application of more sophisticated models to estimate exposure. As with terrestrial assessments, the refinement is done qualitatively rather than quantitatively by integrating information on calculated exposure, estimates of exposure from field measurements, laboratory toxicity tests, field and simulated field assessments of effects, and fish and aquatic organism incident reports.

The assessment of the weight of the evidence for THIMET® in aquatic systems is found in section 6.2.1 of the Ecological Risk Summary.

6.1.2. Uncertainty analysis--risk index

The risk index used in aquatic systems has similar uncertainties to the LD_{50}/ft^2 index. Each of the factors in the deterministic model for estimating the EEC has associated variability that is not incorporated in the calculated exposure estimate. Also, all the factors that can affect the movement of THIMET® from a field into a water body are not included in the model. THIMET® is used on various crops throughout a wide range of climatic conditions. The model attempts to provide an estimate of the exposure of a chemical under typical conditions, but provides little insight into the range and distribution of exposure values, from which the EEC is only a single point estimate. Many of the input variables used the most conservative estimate, consequently the calculated exposure estimate is a conservative estimate, but its location in the probability distribution of estimated values is unknown.

Although GENEEC and other farm pond models are used for screening assessments of aquatic risk, their usefulness for estimating risk to marine and estuarine organisms may not be appropriate. Tidal action and dilution should rapidly reduce any exposures that occur.

The LC_{50} values were variable among studies conducted on the same species (e.g., bluegills ranged from 1.0 to 4.0 µg/L and cutthroat trout ranged from 44 to 340 µg/L). The toxicity values also varied considerably between studies conducted with technical phorate and THIMET® 20G. This variability in toxicity data is not reflected by using only the lowest value in risk estimation.

Given the short half-life of phorate in water, it is unclear how well chronic studies with continuous concentrations of phorate in the test systems reflect the conditions in the field where inputs of phorate into aquatic systems are episodic (possibly single events) and where most of the residues will exist as phorate sulfoxide and phorate sulfone rather than the parent phorate. Chronic risk also is uncertain because the toxicity of these degradates is unknown.

6.2. Risk Description

6.2.1. Ecological risk summary

Phorate is highly toxic to fish and other aquatic organisms, but risks to survival and reproduction exist only if there is unintended exposure of phorate and its degradates to bodies of water. This exposure most often occurs from surface runoff following heavy rainfall events. Since THIMET® is applied with ground equipment for all crops, there is very little likelihood of direct exposure of the granules to water bodies.

Based on the EEC/LC_{50} risk index, the use of THIMET® exceeds the level of concern established by USEPA for both fish and aquatic invertebrates following banded and surface applications. Evidence from limited field incident reports indicates that the use of THIMET® at planting can result in fish kills. However, the focus of this ecological risk assessment is to evaluate the available information to determine the nature and extent of effects to aquatic organisms from the currently labeled use of THIMET®.

The USEPA uses a deterministic model to estimate the environmental concentration of phorate in water due to runoff from sites treated with banded applications THIMET® 15G or 20G at a maximum of 1.3 pounds active ingredient per acre. Although the model provides a point estimate at several times after a runoff event, it does not capture the great potential for variability in the resulting phorate concentrations in water bodies. The model assumes that a runoff event occurs two days after application, but runoff may occur sooner or not at all. If runoff occurs, the proportion of active ingredient leaving the crop field will vary greatly depending on tillage practices, slope, and water holding capacity of the soil. If runoff surface water leaves a field, the likelihood of it affecting aquatic organisms is a function of the proximity of the field to a receiving water body. **Consequently, the risk to aquatic organisms is highly dependent on site-specific conditions. Risks are expected to be higher at sites with 1) more frequent heavy spring rains, 2) soils with low water holding capacity, and 3) rainfall runoff moving directly into water bodies.**

Only three aquatic field incidents were found in the EIIS database report that did not involve cases of misuse. All three occurred in Illinois at the same time in 1970 as a result of heavy rainfalls occurring soon after planting. Five additional fish kill incidents have been reported by American Cyanamid between 1992 and 1995. Three occurred in 1993 in Iowa as a result of one rainfall event. Based on the fish kill incident reports reviewed, it seems that the greatest risks to aquatic organisms occur when farm ponds and other small water bodies receive runoff surface water from nearby treated fields after heavy rainfall. Phorate exposure to populations of aquatic organisms is extremely variable. Most populations of aquatic organisms in the range of THIMET® use probably receive little or no exposure from phorate, especially for populations in areas with infrequent heavy spring rains or that are not located near treated fields. Where exposure does occur, rainfall events must have been sufficient to produce runoff of surface water containing phorate residues, and water bodies must be near enough to treated fields that runoff water still carried toxic concentrations of phorate. If precautions are not taken by growers to reduce the concentrations of phorate entering water bodies, the high toxicity of phorate can result in acute mortality of aquatic organisms.

The aquatic field study of the effects of THIMET® 20G documented runoff events, pond water conditions, and invertebrate and fish populations throughout a growing season in Iowa. Even though heavy rainfalls occurred that resulted in large volumes of runoff into the monitored ponds, the investigators did not detect pesticide-related effects on the invertebrate and fish populations. They also did not find phorate in samples of the runoff water or pond water. Only the sulfoxide and sulfone were detected in the water samples, though their toxicity to aquatic organisms is uncertain.

Although the risk quotients indicate the greatest potential risk in aquatic ecosystems is to invertebrates, as represented in laboratory tests by scud (*Gammarus fasciatus*), species vary considerably in their sensitivity to pesticides. The most sensitive species of aquatic invertebrates may experience a local reduction, but the total invertebrate biomass may not be reduced because of tolerant invertebrate species so that the food base for fish is unaffected. Shifts in species composition have been documented in field studies with other organophosphate insecticides (Giddings *et al.* 1996).

6.2.2. Uncertainty analysis--field studies

As discussed in Section 4.2.2, the use of incident reports in a risk assessment carries many uncertainties. The presence of confirmed incident reports provides positive evidence of the conditions under which pesticide poisonings may occur and some insights into the magnitude of effects if causes and conditions are clearly documented. Poorly diagnosed and poorly documented incidents provide more confusion than insight. On the other hand, the absence of incident reports is not always a clear indication that incidents do not occur. Mineau (1988) suggests that incident reports based on voluntary notification of kills provides a biased reflection of the direct lethal effects of granular pesticides to birds, under-representing kills of small, widely dispersed birds such as breeding songbirds. Similarly, Grieg-Smith (1994) cautioned that although incident monitoring is a useful tool as a relative index of problems, it is a weak method for conclusively establishing a lack of effects. Reporting of fish kills may be much more frequent than birds kills because American Cyanamid and other registrants often compensate farmers for lost fish or assist with restocking. No comparable incentive exists for incidents with terrestrial wildlife. In aquatic systems, the incident reports show the linkage between fish kills and the specific environmental conditions and agricultural practices leading to off-field runoff.

The quality of incident reports is another source of uncertainty. Many of the incident reports in the U.S. EPA EIIS database identify THIMET® as the probable or possible cause of the incident. However, the quality of the diagnostic investigation varied considerably and other plausible explanations for the fish kills may exist. Not all fish kills that are observed in ponds found in agricultural watersheds are due to pesticides. Because the ratio of the volume of runoff to the volume of pond water may be very large for the small ponds often found in agricultural watersheds, the chemical and physical characteristics of these systems can change very quickly when runoff displaces the water originally in the pond. The accounts of the three 1970 fish incidents in Illinois reported that the ponds were very turbid and full of soil and field debris. Fish in such situations have limited access to refugia and may have less time to adapt to changing conditions then fish in larger ecosystems. Consequently, stress factors in the environment of these small ponds are very high, and may confound efforts to establish single causative agents.

Because influx of THIMET® into ponds in agricultural watersheds tends to occur most frequently in warm weather after a runoff event that could enrich pond water with nutrients, an assessment of the oxygen concentration in ponds is desirable, especially if no pesticide residue analyses are available.

Ammonia (NH_3) and ammonium (NH_4+) salts are frequently used fertilizers that are often applied in large quantities in agricultural watersheds. Both ammonia and ammonium are mobile in the soil solution. Both forms are toxic to fish, particularly NH_3. The 96 hr LC_{50} of ammonia for bluegill reported by Ruffier et. al. (1981) is 0.40 to 1.30 mg/L. Ammonia should be considered as a possible cause for fish kill events in recently fertilized watersheds since large runoff events could transport potentially lethal quantities of ammonia to ponds. In most available records of fish kill investigations, it is unclear whether investigators attempted to determine whether ammonia was a contributing factor.

The introduction of very high levels of clay turbidity are often associated with runoff in agricultural watersheds. Although turbidity alone is not likely to be lethal to fish, the stress that it causes can increase the susceptibility of the fish to other stressors in the environment such as disease, low oxygen concentration, ammonia, or pesticides. Because of its potential ability to exacerbate the effects of other environmental factors, the impact of turbidity should be considered when attempting to assess the events surrounding a fish kill.

In summary, incidents of fish kills can provide insights into the geographic and environmental variables most likely to contribute to large runoff events that move pesticide residues into water bodies. However, several confounding sources of stress complicate the diagnosis in fish kill incidents. These confounding factors should be considered when determining the degree of certainty of the diagnosis. The quality of the diagnosis of existing fish kill incidents is highly variable.

6.2.3. Interpretation of ecological significance

There are incidents in the USEPA EIIS database in which runoff from fields treated with THIMET® reportedly resulted in the death of fish in farm ponds. While this may represent a significant loss of a resource to the pond owner, its ecological significance must be kept in context. Most farm ponds are artificially created and stocked. Farm ponds are usually located in lower elevation areas to receive inputs from a localized watershed. They are usually disconnected from natural water bodies, and therefore have limited significance in maintaining the genetic diversity of populations of native species. It is clear that farm pond designs need to consider water quality issues when phorate or other highly toxic pesticides are used in watersheds acting as water supplies.

With all surface-applied granular pesticides, exposure to aquatic systems is extremely variable and dependent on site-specific conditions. The small number of reported fish kill incidents and the lack of apparent effects on fish and invertebrate populations in intensively studied ponds that experienced runoff from fields treated with THIMET® do not suggest that the agricultural use of THIMET® results in widespread or repeated effects to aquatic organisms.

7. Summary

This ecological risk assessment of THIMET® Soil and Systemic Insecticide reflects data from a wide variety of sources, including laboratory and field studies with THIMET® and related studies on granular pesticides and the ecology of agricultural ecosystems. Laboratory studies have demonstrated that THIMET® is highly toxic to many fish and wildlife species. Field studies have added to the understanding of ecological risks from agricultural use of THIMET® by demonstrating the great variability in exposure potential for fish and wildlife and identifying the environmental variables that most affect exposure.

We concluded that the greatest potential risk to terrestrial species from the use of THIMET® occurs when treated fields are temporarily flooded by rainfall or irrigation or where phorate enters shallow waterbodies (e.g., ponds, drainage ditches) during periods of field runoff. Many of the reported wildlife incidents involve exposure to phorate in and around water. Although 95% of THIMET® is used on cotton, corn, potatoes, sugarcane, or peanuts, only one of 11 incidents reported in the NAPIAP survey came from one of these crops (i.e., corn) and none of the 17 incidents reported in the EIIS. The largest bird kill reported (i.e., over 2000 blackbirds in a wheat field in California in 1982) was an aerial application, which is no longer a labeled application method. The discontinuation of aerial applications of THIMET® on all crops significantly reduced the risk of direct application of granules to water bodies. Overall, there is not a clear pattern indicating the species at greatest risk, but most of the larger incident reports involved waterfowl or other birds using a water source containing phorate residues, and most of these incidents were cases of misuse of the product. Also, most of the wildlife incidents occurred from October to March, which is outside the breeding season of most species. Consequently, **the weight of evidence does not suggest a repeated pattern of mortality and/or reproductive effects from the registered use of THIMET® sufficient to impact populations of terrestrial wildlife.**

Risks to aquatic ecosystems also are highly variable because exposure is dependent on heavy rainfall events that result in runoff from treated fields to nearby water bodies. Phorate is highly toxic to aquatic organisms once it enters a water body, and the pattern of field kill incidents indicates that lethal exposure concentrations may occur in farm ponds near treated fields following heavy rainfall. An aquatic field study of THIMET® did not find treatment-related effects on populations of phytoplankton, zooplankton, macroinvertebrates, and fish. Despite being used on several crops for over 40 years, relatively few incidents involving fish mortality have been reported. Consequently, **the weight of evidence identifies specific conditions where phorate may adversely affect aquatic organisms in localized settings (e.g., farm ponds adjacent to corn fields during heavy rains), but does not indicate a repeated pattern of mortality sufficient to impact regional populations of aquatic organisms.**

This assessment, as well as the ecological risk assessment conducted by USEPA, uses deterministic quotient indices to characterize risks and therefore represents a first tier screening assessment. This assessment also integrates laboratory data with data from field studies and incident reports to develop a narrative synthesis of the overall risks to fish and wildlife. As suggested by the Aquatic Risk Assessment and Mitigation Dialogue Group (1994) and again by the USEPA Science Advisory Panel in May, 1996, probabilistic risk assessment may be a more appropriate approach to characterization of ecological risks for making regulatory decisions.

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